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A SYNOPTIC CLIMATOLOGY OF DIURNAL INVERSIONS IN THE JORDAN VALLEY

Charles Ray Dickson

Utah University
Salt Lake City, Utah

August 1957

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A SYNOPTIC CLIMATOLOGY OF DIURNAL INVERSIONS IN THE JORDAN VALLEY

by

Charles Ray Dickson

Department of Meteorology

University of Utah

August, 1957

PROGRESS REPORT

on

THE EFFECT OF ATMOSPHERIC FLUORIDES ON MAN

Cooperating Agencies and Personnel

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Red Butte Canyon, area in study.

INTRODUCTION

This report presents a synoptic climatology of inland diurnal temperature inversions with specific reference to the Salt Lake City Region. A study of local Salt Lake City inversions has been undertaken with consideration of the factors of magnitude and depth of inversion, sky cover, temperature, wind direction and velocity at the surface, at 7000 ft. and at 10,000 ft., and upper air and surface synoptic conditions. These factors have been studied in an attempt to classify inversion patterns of this area and to see if any natural control can be discovered which has significant influence upon the occurrence and structure of inversions.

A purely statistical procedure was not satisfactory in obtaining results. Many of the problems were not clearly explainable in statistical form. Unless the synoptic approach was used, many of the situations were poorly understood and they could not be fitted into any particular pattern. Therefore, synoptic evaluation was necessary before any real results were obtained.

An additional analysis was made of the climate of Salt Lake City with special regard given to the habitability of the area. This was done by the author because of his interest in medical climatology.

PREVIOUS WORK IN INVERSION RESEARCH

Much work has been done on the subject of inversions on both the European and North American continents. A summary of various studies through the years furnishes a background of the work on inversions which has already been completed. This type of review also illustrates the procedure, problems, and conclusions of the past.

Sir N. K. Johnson (1) made a study in Porton, England, of the vertical gradient of the temperature near the ground. Hourly readings of temperature were made during 1923-1925 near Porton, on top of a low ridge, at levels 1.2 m., 7.1 m., and 17.1 m. above the ground. Included in this study were mean hourly temperature gradients in each month, frequencies of temperature inversions in specified classes, and values of maximum inversion, all for the height intervals 1 to 7 m. and 1 to 17 m. The amount of maximum inversion ranges from 4F to 6F at 1 to 7 m. and 5F to 10F at 1 to 17m. with the highest recorded range being 10.2F. (1-17 m.); almost all cases of maximum inversion occurred under clear or nearly clear skies with little or no wind.

Another early contributor to the field of formation of surface inversions is Rudolph Steiner (2) of Germany. Dr. Steiner's studies were concerned with the formation of nocturnal radiation inversions at Rostock, under various combinations of sea and land breeze and clear and cloudy skies. The study was made with the aid of data from a large number of kite ascents made in 1925-1926. These soundings were made at intervals of a few minutes, usually from mid-afternoon to about ten P.M. There were observational data,

including pressures, temperature, humidity, wind and vapor pressure at the surface and at levels up to 700 m. With an east wind (land breeze) and clear anticyclonic weather, a slight upper inversion (advective) usually forms 1-2 hours before sunset becoming nearly isothermal at sunset; a surface inversion follows. The rate of radiational cooling is shown to be dependent on the vapor content of air.

Earlier studies done in Europe show interesting results. Johnson and G.S.P. Heywood (3) investigated the lapse rate of temperature in the lowest hundred meters of the atmosphere. The Johnson and Heywood study was based on an excellent series of hourly observations made on a wireless mast at Leafield, England, over a period of five years (1926-1930). Temperature was measured at 1.2 m., 12 m., 31 m., 57 m., and 88 m.; wind was measured at 13m. and 95 m above the ground. Monthly tables and graphs were given showing the hourly mean temperature differences between the various levels and mean temperature height curves for each hour and month. The curves for June and July showed that the nocturnal inversion is larger in summer than in winter, but persists for a much shorter time. The frequent existence of inversions in the lowest levels (up to 15 meters) with isothermal or near-normal lapse rates prevailing higher up, was clearly revealed. Special tables gave the percentage frequency of occurrence of various magnitudes of lapse rates and inversions, along with the maximum values of both, in each month. In the five-year period, the greatest hourly inversions amounted to 10F. between 1.2 m. and 12 m., and 9F between 57 m. and 88 m. The sky was almost always clear at the time of the maximum inversion over the height interval 1.2 m. to 12 m. Radiation fogs were often less than 88 m. in depth and

usually a large inversion existed above the fog layer. Wind speeds were invariably small at the time of maximum inversion. Strong winds tended to destroy otherwise persistent inversions.

An excellent series of tri-daily observations of dry and wet bulb temperature and wind speed, made by captive balloons at Cardington, Bedfordshire, England, were taken by J. B. Shaw (4) in 1949-1953. These provided a detailed view of the temperature structure up to 2000 ft. Mean values of temperature difference between 4 ft. and 30 ft., 50 ft., 100 ft., 250 ft., and every 250 ft. interval thereafter to 2000 ft., were given for each season for classes of wind speed and cloudiness, as present at 0700 GMT and 1800 GMT. Surface temperature inversions were most pronounced in autumn. At the morning hour the top of the inversion may easily reach a height of 1000 ft., and its magnitude may be as much as 9F per 1000 ft. In general the effect of cloudy sky is to lower the top of the inversion, as well as reduce its strength. The effect of increasing wind speed is less regular, although moderate winds tend to diminish the magnitude of the inversion, and strong winds, particularly if combined with cloudy skies, resulted in a lowering of the inversion top.

Some of the early studies carried out in the United States were those made by United States Weather Bureau meteorologists. One of these studies in particular, was that carried out by H. J. Cox (5) in 1912-1916. This work was concerned with the Thermal Belts and inversions of temperature in the North Carolina mountain region. Thermoscreen records from a special network of stations operated in the mountain region of North Carolina by the

United States Weather Bureau afforded special insight into the character of temperature inversions throughout the year. On the average, inversions occurred three out of four nights, and they were frequent in May and November, occurring in both cyclonic and anticyclonic situations. The greatest inversion observed was 31F per 1000 ft. on Brown Mountain.

Another Weather Bureau meteorologist interested in this type of problem was Floyd D. Young (6) who made a nocturnal temperature inversion study at Medford, Oregon, and Pomona, California, during the frost seasons of 1918-1920. This pursuit revealed many interesting facts regarding the stratum of cold air which collects in valleys on clear, calm nights, following warm days. At Pomona, differences in minimum temperatures as great as 28F. were observed between stations at the base and 225 ft. above the base of a hillside, but the greater part of the inversion occurred in the lowest 50 ft. At Medford, nearly all of the nocturnal inversions occurred in the lowest 150 ft. The maximum temperature difference on a 300 ft. tower located at a site nearly equidistant from the hillside observing points to either side of the valley, was 13F. The free-air gradient observed on the tower was steeper than the hillside gradients.

A very recent report carried out by the United States Weather Bureau (7) for the United States Atomic Energy Commission was a meteorological survey of the Oak Ridge area. One of the features of the elaborate observing network at Oak Ridge, Tennessee, was the excellent series of temperature observations, which included measurements by captive balloon thermistor (July 1949-November 1950), hourly and six-hourly thermopile (June 1950-October 1951), and thermohn (continuous from January 1944), plus readings

at grass and shelter levels and various heights up to 1000 ft. In this report, rather complete frequency distributions of temperature differences were given for pairs of levels, by season, time of day, and degree of cloudiness. Of special interest were graphs showing the diurnal course of the base and top of the nocturnal inversion in the fall of 1950, as well as the monthly percentage frequency of inversions, based on data for 1944-1951. Intense shallow inversions usually formed in the early evening (8F per 500 ft. with some cases 15F.), increasing slowly in depth, but not intensifying after ten P.M. The frequency of nocturnal inversions in winter was 70% and in the fall it was 95%. The overall frequency of inversions, exhibits maxima in October (63%) and March (60%), and minima in July (49%) and January (52%).

Donald Shearer (8) in 1956 compiled a General Climatology of Dugway Proving Ground. A section of his report concerned the stability of air near the ground, as determined from temperature observation at 0.5 and 4.0m. above the ground. On the average, a moderate inversion prevails at night. Winter has the least stability. The greatest extremes of stability occur in the summer months, when the night-time inversions are on the order of 3 to 6F. and have been known to reach 12F. Clear dry nights in spring and summer are ideal for nocturnal radiational cooling.

A PHYSIOGRAPHY OF THE JORDAN VALLEY

The area under consideration in this work occupies the Northeastern portion of the Jordan Valley; an intermontane basin encircled on three sides by mountains, and joining on the remaining side with a flat plain. The valley is approximately 16 miles wide and 20 miles in length. In the center lies the Great Salt Lake, the largest highly saline body in North America. The southern boundary of Jordan Valley is formed by the low east-west trending Traverse Range.

This range is divided into two equal parts by the water gap of the Jordan River, the northward-flowing stream that connects the fresh water Utah Lake in the neighboring valley to the south, with Great Salt Lake, lying to the northwest of the Jordan Valley. The western border of this valley consists of the Oquirrh Range, which extends to an elevation of 8500 feet with peaks extending to a height of 9700 feet.

The eastern margin of the valley is formed by the loftier Wasatch Range, the higher summits near 12,000 feet MSL. Two main canyons break the lofty range of the Wasatch Mountains — Emigration and Parley's, which add greatly to mountain-valley wind system. The valley floor proper consists of two parts: a broad, flat central plain with an elevation of approximately 4225 feet, and a narrower lacustrine terrace that intervenes between the central flat and the bordering mountains, which rise abruptly to elevations of 8000 feet. Both the plain and the surrounding terraces are parts of the former lake bottom of ancient, prehistoric Lake Bonneville, probably of late pliestocene age (9).

To further locate the area: the Jordan Valley lies in the north-central part of Utah, opposite the south central section of the Wasatch Range. To the west is the Great Basin section of the Basin and Range physiographic provinces (10), which extends through western Utah and across Nevada to the eastern base of the Sierra Nevada Mountains.

Mr. H. Jacobsen and Mr. P. Williams of the U. S. Weather Bureau launching Radiosonde balloon.

Balloon after release.

PROCEDURE

This present study is limited to ten months: 8 August 1956 to 31 May 1957 inclusive. The ten-month period of observation was selected because the author believed that these ten months would show a trend toward the over-all average for a longer period of time. The time was also selected because of the valuable data which were available.

On 8 August 1956 at the Salt Lake Airport, the United States Weather Bureau began, four times daily, radiosonde observations. Due to the international agreement of the World Meteorological Organization, the times for collecting and transmitting the data were changed as of 1 June 1957. The use of data received at different hours was not considered valid for comparison with the previous ten-month's data, (see Table 1).

Beginning in August 1956 and running to June 1957, the following 14 data were recorded four times each day from Salt Lake Airport surface and upper air data at 0230, 0830, 1430, and 2030 MST.

1. Occurrence of inversion
2. Degree of inversion
3. Thickness of inversion
4. Surface wind at time of inversion
5. Wind velocity in knots at surface
6. The 7000 ft. wind direction
7. Wind velocity in knots at 7000 ft.
8. The 10,000 ft. wind direction
9. Velocity of wind in knots at 10,000 ft.
10. Sky cover at time of inversion
11. Relative humidity at time of inversion
12. Temperature at surface
13. Report of the troughs
14. Report of the ridges

TABLE 1

SOURCES OF DATA

STATION OR AGENCY	ELEVATION	COORDINATES LATITUDE	LONGITUDE
Salt Lake Municipal Airport U.S. Weather Bureau	4220 ft.	40°46'	111°58'
Salt Lake Heating and Power Division	4260 ft.	40°45'	111°53'51"
University of Utah	4737 ft.	40°45'38"	111°49'42"
Inversion Project #1	5160 ft.	40°45'58"	111°49'14"
#2	5056 ft.	40°46' 6"	111°49'15'
#3	5160 ft.	40°46'12"	111°49'21"
#4	5160 ft.	40°46'30"	111°49'38"
Post Engineer	4940 ft.	40°46'	111°49'40"

Figure 1 illustrates how the record from the Weather Bureau station was kept. The fifty daily entries in this ten-month record from the Weather Bureau constituted one of the main sources for information.

Another important source of material was the climatological records of the Department of Meteorology at the University of Utah. This station has an elevation of 4737 ft. and is located eight miles east of the Weather Bureau station. Five principal items were taken from the University record:

1. Hourly temperature record - 24 hours a day taken from thermograph charts
2. Wind direction at surface
3. Velocity at surface
4. Relative humidity
5. Minimum and maximum temperature daily

The Fort Douglas Post Engineer's Office (4940 ft.) was the third source of data. This office was able to make available two main items:

1. A daily thermograph chart
2. The maximum and minimum temperature daily

Red Butte Canyon was the site for further observations. This canyon area is 5160 ft. in elevation. Three individual stations were established in Red Butte, and in the spring of 1957 a fourth station was added. These thermoscreen stations were installed by Professor A.H. Thompson and the author, (see Figure 2). While these stations were in operation, data were received from them which proved useful in the study:

1. Hourly temperature record - 24 hours a day taken from thermograph charts
2. Continuously recording hygrothermograph charts from two stations, #3 and #4.

(See Figure 3)

FIGURE I

SAMPLE DATA SHEET

SALT LAKE AIRPORT 0830 MST 27 SEPTEMBER 1956

Upper Air Ridges (700mb)	0
Upper Air Troughs (700mb)	x
Surface High	0
Surface Low	x
Surface Temp.F	60°
Relative Humidity	35%
Sky Cover in tenths	10
10,000 feet Velocity	15 KNOTS
10,000 feet Wind Direction	SW
7000 feet Velocity	15 KNOTS
7000 feet Wind Direction	SSW
Surface Wind Velocity	8 KNOTS
Surface Wind Direction	SSE
Thickness of Inversions	345 FEET
Magnitude of Inversion	6°
Occurrence of Inversion	YES
Date	9-27

FIGURE 2

Author changing thermograph chart. This is a standard type shelter used in this study.

FIGURE 3

Instrument shelters #1 and #3. Towers in the background are being used in another phase of the inversion research.

The Salt Lake City Corporation assisted in the study, making information available from data recorded by Power and Heating Division, a station of 4260 ft. The office at 9th South and 2nd West in Salt Lake City furnished the following information for the record August 1956-June 1957:

1. A thermograph record
2. Daily maximum and minimum temperature

A sixth source of help came from Phillip Williams, Jr., Research Forecaster for the United States Weather Bureau at Salt Lake City. His personal observations added to the information.

The first five data sources lie almost in a west-east straight line passing through the center of downtown Salt Lake City. Their relative horizontal distance and elevations are shown schematically in Figures 4, 5, 6.

TYPES OF INVERSIONS

On the average the air temperature decreases along the vertical, but under certain conditions temperature increases with altitude. This is called an inversion. Inversions are often found in connection with frontal surfaces, which are large scale moving sloping layers of transition between large bodies of air having different properties. Other inversions, which are quasi-horizontal, are produced by radiation or sinking within an originally homogeneous body of air. This study shall be concerned primarily with this type.

FIGURE 5

Instrument shelters #1 and #3.

FIGURE 6

Profile of valley and Red Butte area.

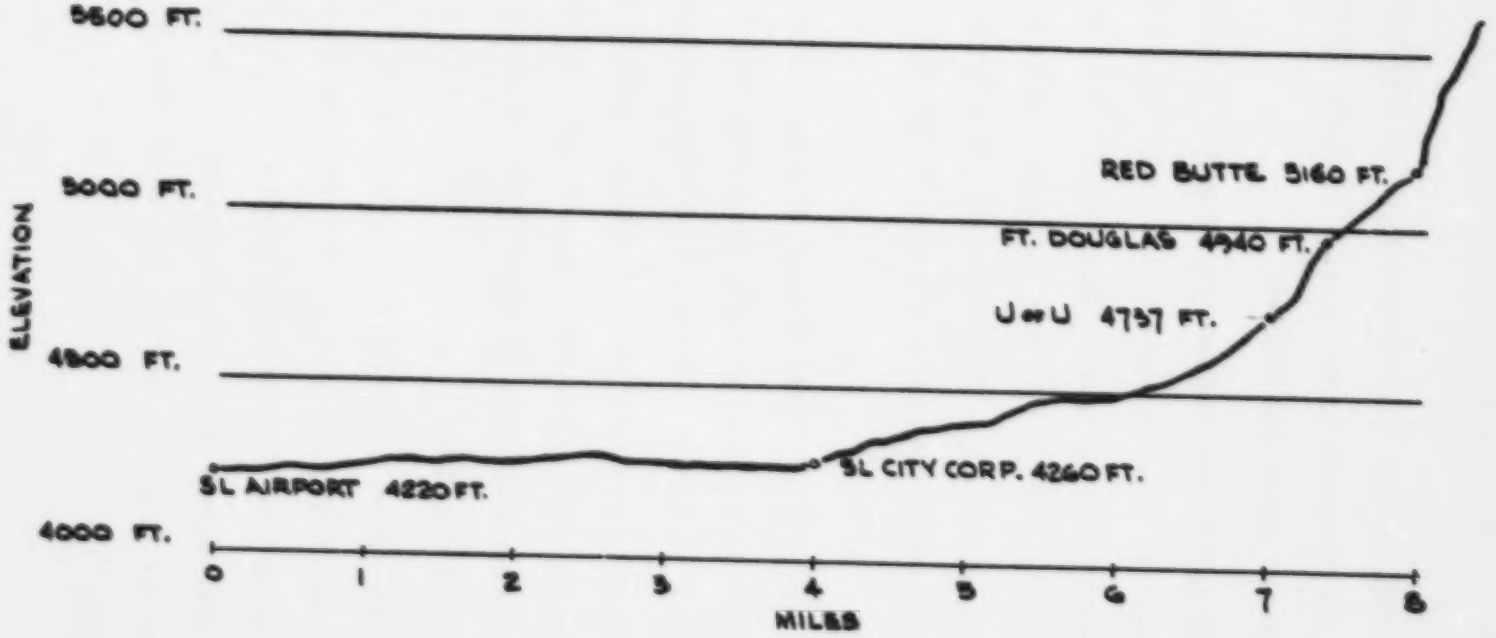


FIGURE 4

DISTRIBUTION AND ELEVATION
OF STATIONS

An essential feature of an inversion is the pronounced stability of the air within the inversion layer. A well-developed inversion acts as a "lid" that damps out convective currents.

The processes responsible for the formation of inversions can usually be recognized from the distribution along the vertical of the temperature, humidity or dew point. Depending on these processes, the inversions may be classified into four principal types, as illustrated in Figure 7. It is typical of all types that the relative humidity is high and the dew point depression low at the base of the inversion and in the air below it.

If the inversion is caused by surface cooling (Figure 7A), the dew point depression in the cooled air near the ground will diminish, though the mixing ratio will not be affected unless the cooling results in condensation. If the winds are relatively strong, the surface layer will be mixed; the base of the inversion will then be found at some distance above the ground, with a normal lapse of temperature and more or less uniform mixing ratio below the base.

Inversions formed mainly by subsidence (Figure 7B,C) are readily recognized by the pronounced dryness above the inversion. The temperature changes associated with subsidence are usually so large that they overshadow other influences. Subsidence inversions of the type shown in 7C are often observed in air masses that are heated from below or in which winds are strong.

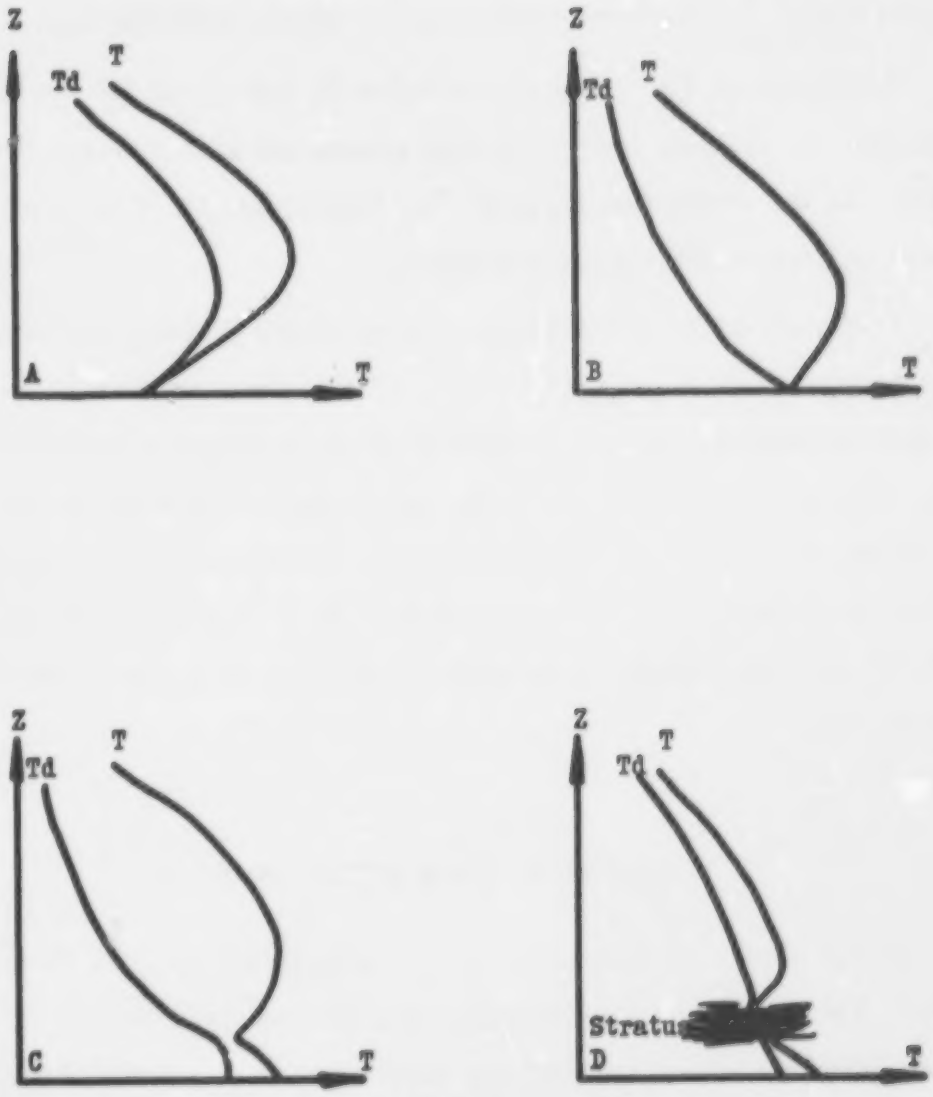


FIGURE 7

TYPES OF TEMPERATURE INVERSIONS
(After Pettersen (11))

A frequent type of inversion is illustrated by Figure 7D. These inversions, which are not necessarily characterized by pronounced dryness aloft, form in air masses which are exposed to surface cooling and mixing. Most frequently, a stratiform cloud layer is present below the base.

Inversions of the type shown in Figure 7A are typical of the polar continental anticyclones during the cold season; and of the arctic in all seasons. In the presence of moderate or strong winds, the inversion layer is found at some distance above the ground.

Inversions with the structure shown in Figure 4C occur frequently in traveling as well as in stationary anticyclones. They are more or less permanent features of the eastern portion of the subtropical anticyclones and of large portions of the trade-wind belt. Particularly during the warm season, extensive cloud sheets (stratus, stratocumulus, or flat cumulus) are present below the base. Inversions of the type shown in Figure 7D are found frequently in traveling air masses in middle and high latitudes (11).

THE DEVELOPMENT OF INLAND DIURNAL INVERSIONS

Inland diurnal inversions are of the type 7A and 7D (with or without clouds). The steps in their development may be summarized briefly as follows: During a clear, calm day the temperature of the ground surface is raised through heat received by radiation from the sun, and the air in contact with the ground is warmed by conduction. This warm air is forced

upward and replaced by cooler and denser air from nearby or above, and a vertical circulation is established, which continues as long as the ground surface is warmer than the air in contact with it. Near sunset the air up to 1000 ft. or more is nearly in adiabatic equilibrium.

After the sun goes down, the surface of the ground loses heat rapidly by radiation to the sky, and its temperature soon falls below that of the air in contact with it. The surface air cools through conduction of heat to the colder ground, and its density becomes increasingly greater. Its increased density tends to keep it in contact with the ground, where it continues to grow colder and colder throughout the night. As air is a poor conductor and radiator of heat, the temperature of the air a few hundred feet above the ground falls quite slowly, and by sunrise a considerable difference in temperature has developed between the air at the surface of the ground and that a few hundred feet above the ground.

SYNOPTIC CLIMATOLOGY OF INVERSIONS

It has been considered preferable to present the data in forms of tables, which are easily read, along with graphs which have a greater visual appeal but are less suitable for giving numerical answers. The data from which the graphs were constructed are found in the appendix.

A. Magnitude of Inversions

For the purpose of this study 548 cases of inversion were recorded. The magnitude of these inversions had a range from 0.5 F to 20 F. On 8 May 1957 at 2030 MST, the maximum of

20F was recorded. The minimum magnitude consisted of several entries which were 0.5F. but later rounded off to 1.0 F for convenience in tabulation. Throughout the paper, the inversion magnitude will be considered in two main classes: (1) less than 5F., and (2) 5 F. or over. Thirty-seven per cent of all of the inversions had a magnitude of 5 F. or more, while sixty-three per cent of the inversions reported a magnitude less than 5 F. Both the average and the most frequent value of magnitude in the study were 3 F. This number occurred 102 times. A complete frequency chart for the entire ten months appears in Figure 8.

A study was made to find the relationship between inversion magnitude and sky cover. A chart was devised in which each month showed the percentage of sky cover (See Table 2). It appears that sky cover lowers the magnitude only if cloud cover of at least six-tenths has been predominate for more than eight day-light hours.

B. Depth of Inversions

The average depth of the inversions under study during the ten-month period was 770 ft. (see Figure 9). December 1956 showed a maximum of 1346 ft. The minimum occurred in March which was only 521 ft. The range of depth was 825 ft. for the ten months.

No specific factor resulting in increase or decrease in the depth of inversion was discovered.

FREQUENCIES OF THE MAGNITUDE OF INVERSIONS

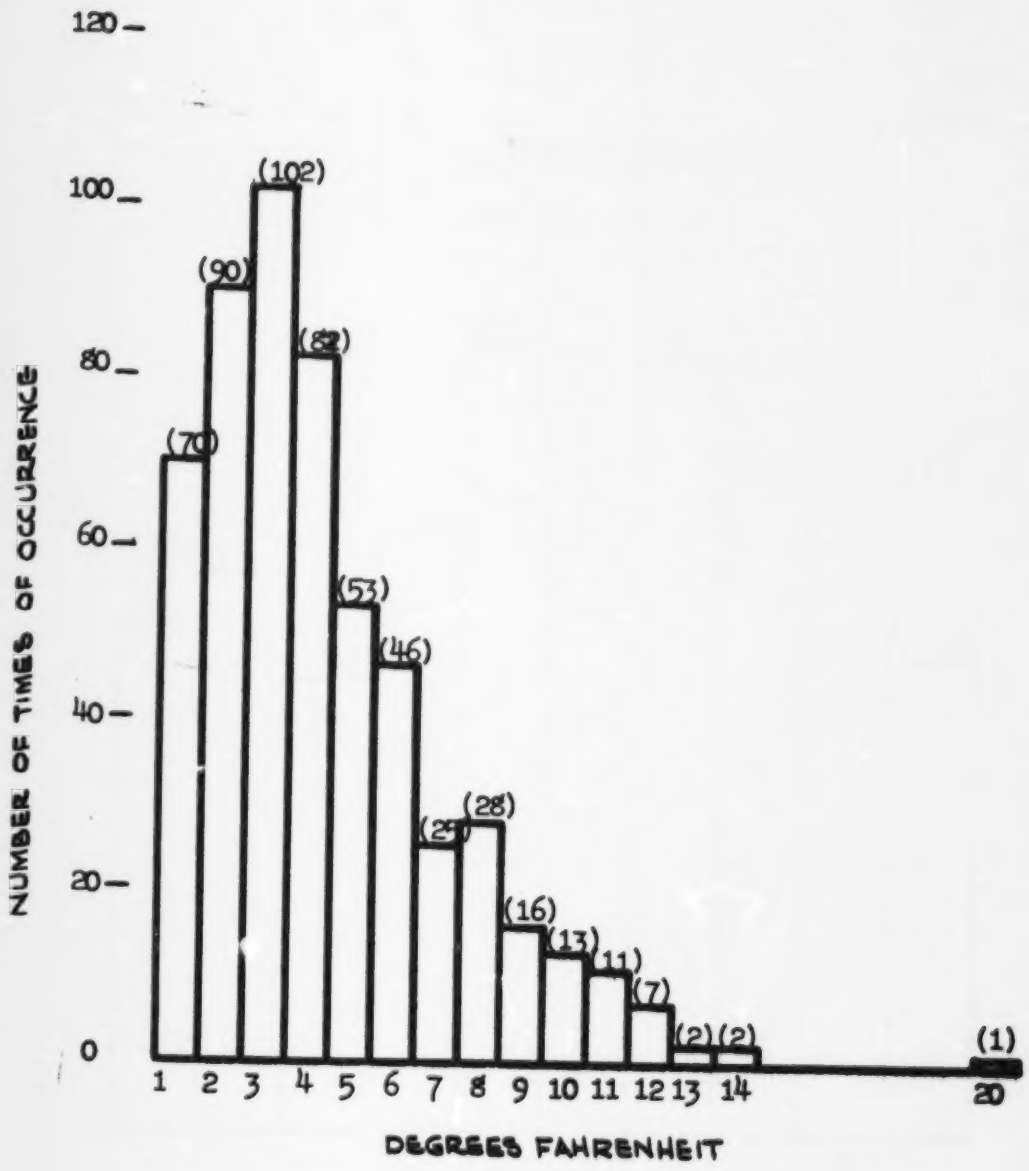
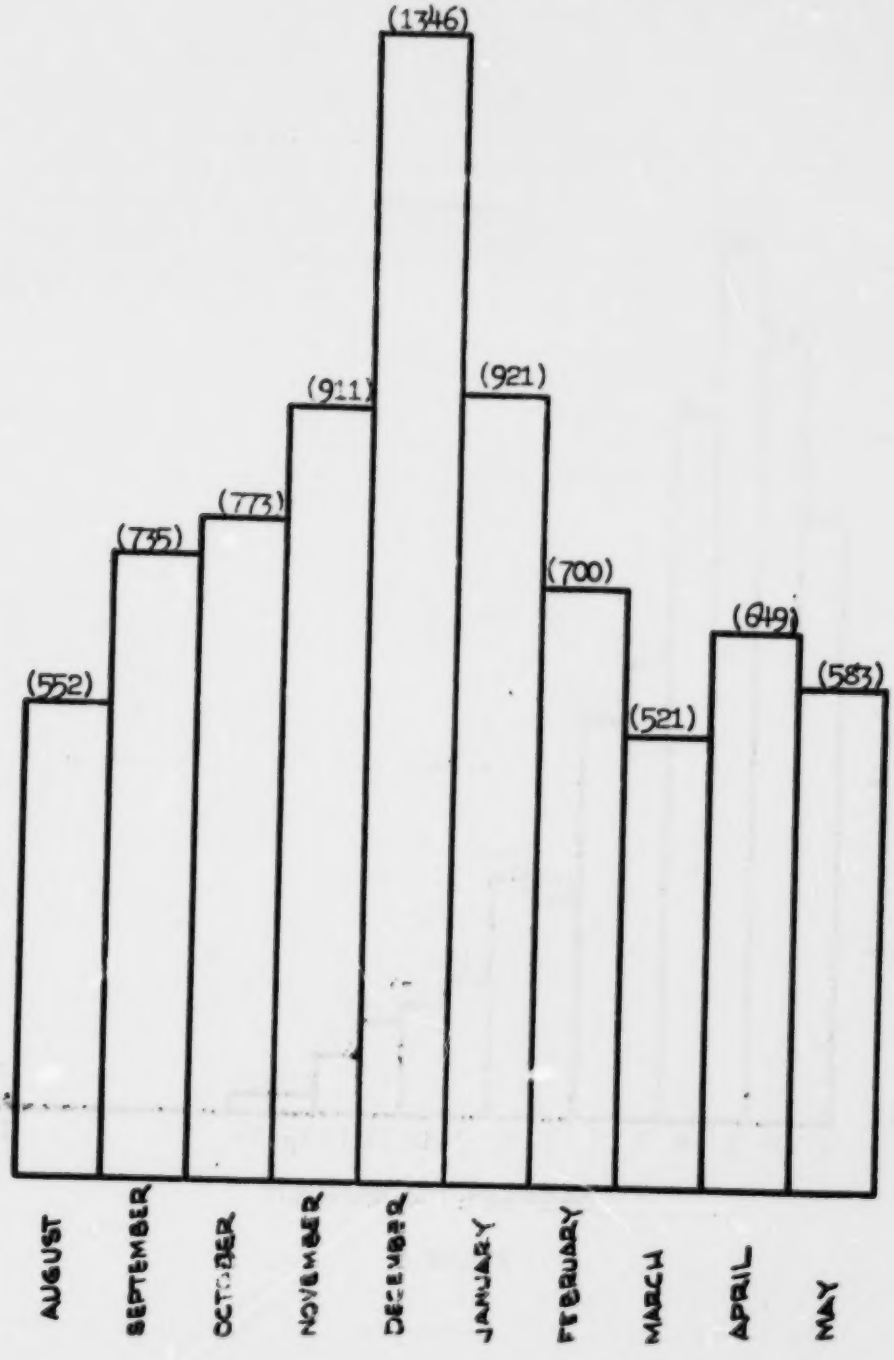


FIGURE 8

FIGURE 9

MONTHLY DISTRIBUTION OF INVERSIONS
ACCORDING TO DEPTH IN FEET



C. Sky Cover

Some degree of sky cover was observed with 371 of the 548 inversions. The minimum cover was reported in May 1956 when there were only 13 reports. However, by August 1956, the cover had reached a maximum of 143 reports. During the entire period, only 32% of the inversions experienced from one to ten-tenths cover. Tables 2 and 3 both show sky cover conditions for each month.

D. Wind

At the Salt Lake Weather Bureau wind was recorded at the surface, 7000 ft. (MSL) and 10,000 ft. (MSL) levels every six hours. In the ten months record, some types of gradient-flow occurred infrequently. During inversion conditions at the surface level, the most frequent direction of the surface wind was southeast, at 7000 ft. it was southeast, and at 10,000 ft. the prevailing direction was southwest.

Some 18% of the inversions occurred with wind velocity over 20 knots at 7000 ft., as shown in Table 4. With wind velocity 20-plus knots at 7000 ft. no significant change in depth was evident but the magnitude of such inversions was decreased if the wind persisted above 20 knots for more than an 18-hour period. The direction of the wind was found to have no significant influence upon inversion. In fact, the records kept in this study concerning the wind direction and velocity at

THE INVERSIONS BROKEN DOWN BY PERCENTAGES
ACCORDING TO
(1) Sky Cover
(2) Magnitude of Inversions

	Month	% of inversions with sky cover	% of inversions when sky is clear	% with 5^0 or over	% which were under 5^0
	August	64	36	58	42
/	September	34	66	57	43
	October	51	49	71	29
+/+	November	67	33	44	56
	December	78	22	51	49
#-#	January	89	11	78	22
-'-	February	76	24	82	18
-'-#-#	March	86	14	89	11
-'-	April	72	28	89	11
	May	69	31	60	40

/ Months in which inversions occurred when the sky was more than 50% free from cover.

#-# Months in which inversions occurred when sky cover was 80% or more.

-'- Months in which 80% or over of the inversions reached a magnitude of 5^0 or above.

+/+ Months in which over 50% of the inversions reported were below 5^0 magnitude.

TABLE 2

TABLE 3

SKY COVER DISTRIBUTION DURING INVERSIONS

AUGUST 1956

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst	1	1	4	1	1	1					9	9
0830-mst	1				1			2			4	2
1430-mst								1			1	
2030-mst	2			1		1	2	2		4	12	4
Totals	4	1	4	2	2	2	2	5	—	4	26	15

SEPTEMBER 1956

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst		1	2	1		1				2	7	17
0830-mst	2		1			1	1	1		3	9	15
1430-mst												1
2030-mst	3	—	—	—	—	—	1	2	—	1	7	11
Totals	5	1	3	1	—	2	2	3	—	6	23	44

TABLE 3 (cont'd)

OCTOBER 1956

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Clear
0230-mst	1		2					4	1	3	11	10
0830-mst		1		1		1	2	2	1	2	10	12
1430-mst												
2030-mst	2		2	1		1	1	1		5	13	11
Totals	3	1	4	2		2	3	7	2	10	34	33

NOVEMBER 1956

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Clear
0230-mst	6	1	1		2	1		1	1	3	16	12
0830-mst	5	3	1	2		2			1	4	18	8
1430-mst										1	1	
2030-mst	1	7	1	1	2	2			1	2	17	6
Total	12	11	3	3	4	5		1	3	10	52	26

TABLE 3 (cont'd)

DECEMBER 1956

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst	1	4	4	3			2	1	1	5	21	6
0830-mst	4	2	2	2				1	3	6	20	5
1430-mst								1		2	3	
2030-mst	3	6			1			1		8	19	5
Total	8	12	6	5	1		2	4	4	21	63	16

JANUARY 1957

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst		1	1	3					2	9	16	4
0830-mst	2		1				3	3	2	5	16	2
1430-mst										2		
2030-mst		2	2					2		14	20	1
Total	2	3	4	3			3	5	4	30	54	7

TABLE 3 (cont'd)

FEBRUARY 1957

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst	2	2	1		2	1	1			9	18	5
0830-mst		1		1		1	1	1	1	8	14	6
1430-mst												
2030-mst		1				1				11	13	3
Total	2	4	1	1	2	3	2	1	1	28	45	14

MARCH 1957

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst			1	1	1		1	1	1	8	14	3
0830-mst	2					1	2			8	13	2
1430-mst					1						1	
2030-mst						2				6	8	1
Total	2		1	1	2	3	3	1	1	22	36	6

TABLE 3 (cont'd)

APRIL 1957

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst	1			1			1	4	3	1	11	5
0830-mst							1			1	2	1
1430-mst												
2030-mst										5	5	1
Total	1			1			2	4	3	7	18	7

MAY 1957

Time of the Observation	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	Total	Time Clear
0230-mst		3	1			2			1	3	10	8
0830-mst					1						1	1
1430-mst												
2030-mst		4			1			2		2	9	
Total		7	1		2	2		2	1	5	20	9

FIGURE 10

FREQUENCY OF SKYCOVER WITH INVERSIONS

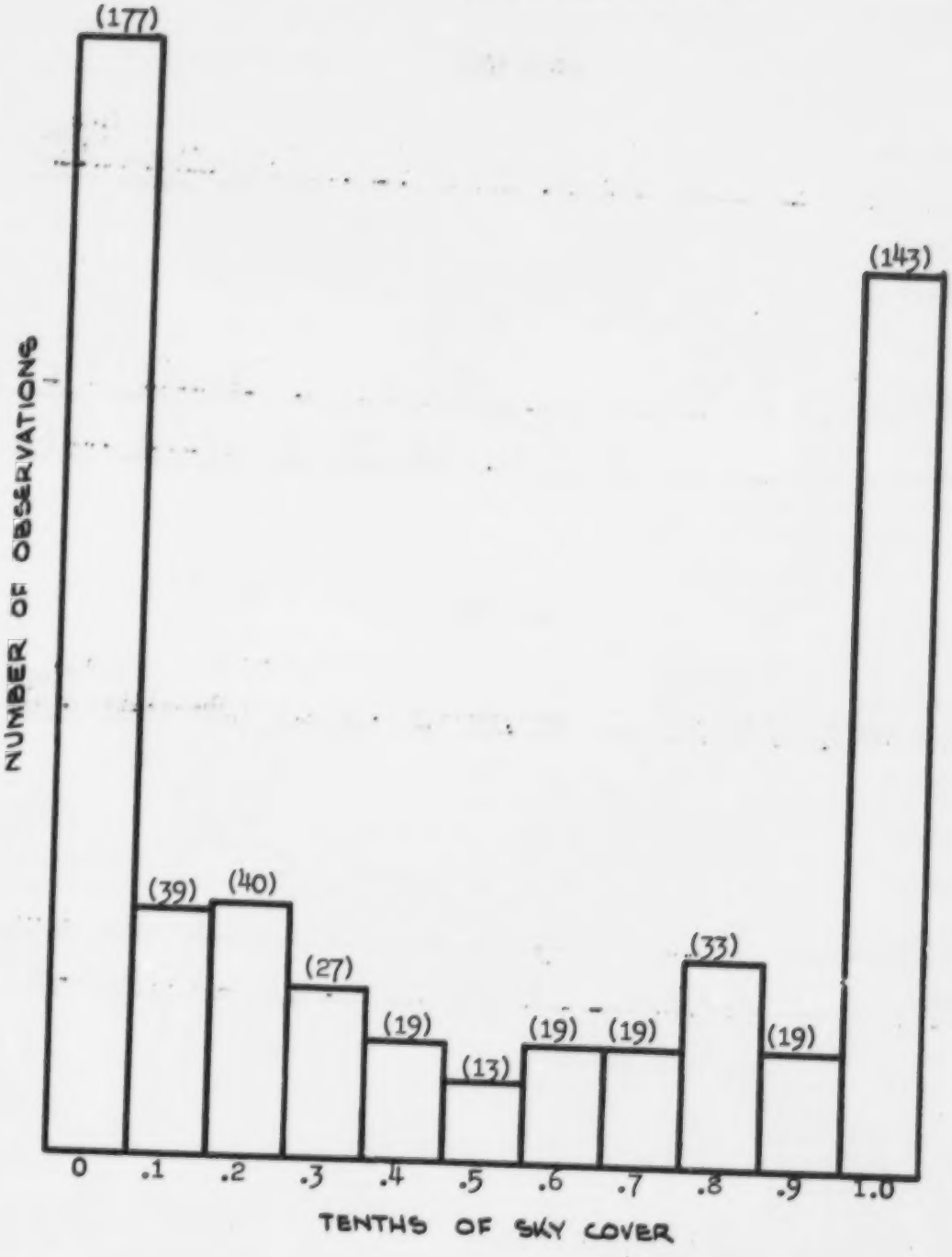
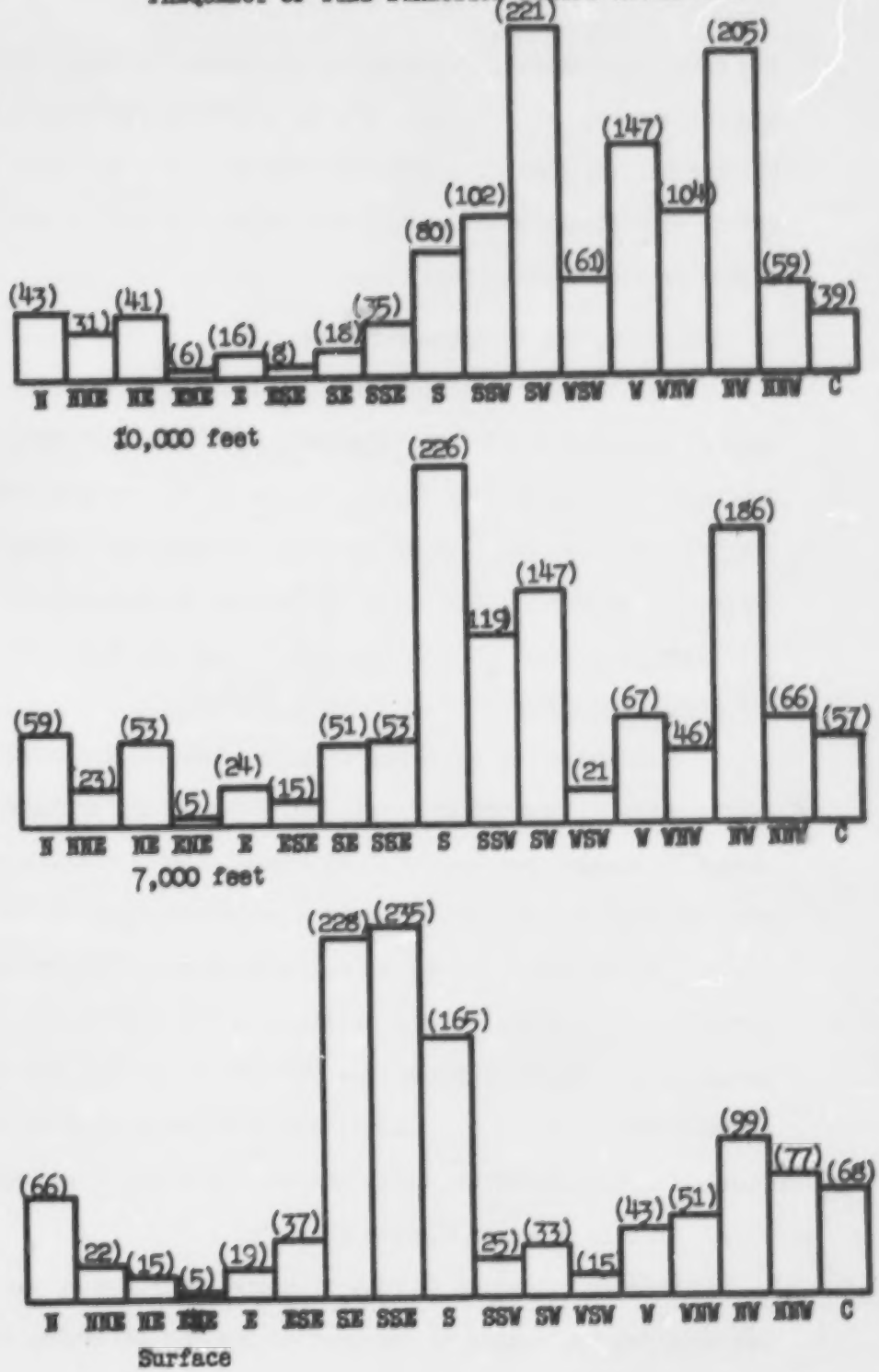


FIGURE 11

FREQUENCY OF WIND DIRECTION DURING INVERSIONS


(43) (31) (41) (6) (16) (8) (18) (35) (80) (102) (221) (61) (147) (104) (205) (59) (39)
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
10,000 feet
(59) (23) (53) (5) (24) (15) (51) (53) (226) (119) (147) (21) (67) (46) (186) (66) (57)
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
7,000 feet
(66) (22) (15) (5) (19) (37) (228) (235) (165) (25) (33) (15) (43) (51) (99) (77) (68)
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
Surface

the three wind levels, corresponded so closely to the climatological averages of Salt Lake City on record at the United States Weather Bureau, that it seemed entirely safe to state that there was no significant relationship between wind direction and inversion structure at this location.

E. Inversions and Synoptic Patterns

Winds were classified from synoptic charts drawn by Weather Bureau personnel for 0230 MST, 0830 MST, 1430 MST, and 2030 MST. In addition to the directions of t sixteen compass points, the classification of the flow includes two groups of pressure structures which cannot be defined by directions: (1) Ridge and Center of High Pressure (Ridge and High) and (2) Trough and Center of Low Pressure.

When under the influence of high pressure at the surface with a ridge at the 700 mb level, the winds at the surface showed no change from the usual southeast direction. The upper air wind flow at 7000 ft. was from a northwest direction at 8 knots. The 10,000 ft. level showed predominance from north-northwest at 17 knots. The climatological data for a 28 year period showed the difference from the results of the short-period study. The 7000 ft. level showed a shift from southerly flow while the 10,000 ft. level showed a shift to a northwesterly flow. This is shown in Figures 12 and 13.

Under a situation of high pressure and ridge in the upper air with the low center to the east in Eastern Colorado, the

FIGURE 12

FREQUENCY OF WIND DIRECTION WHEN INVERSIONS ARE PRESENT
UNDER THE INFLUENCE OF HIGH PRESSURE

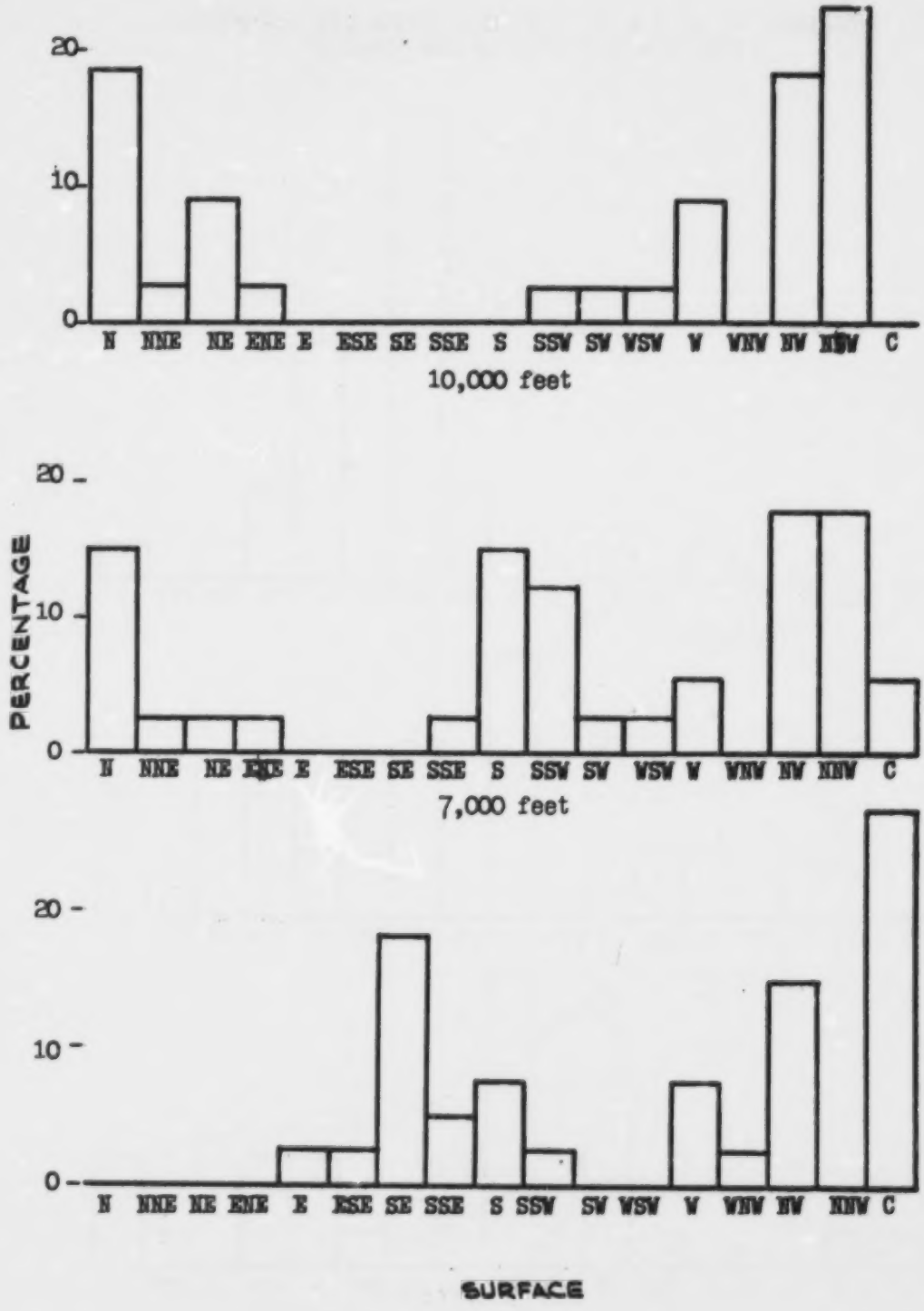
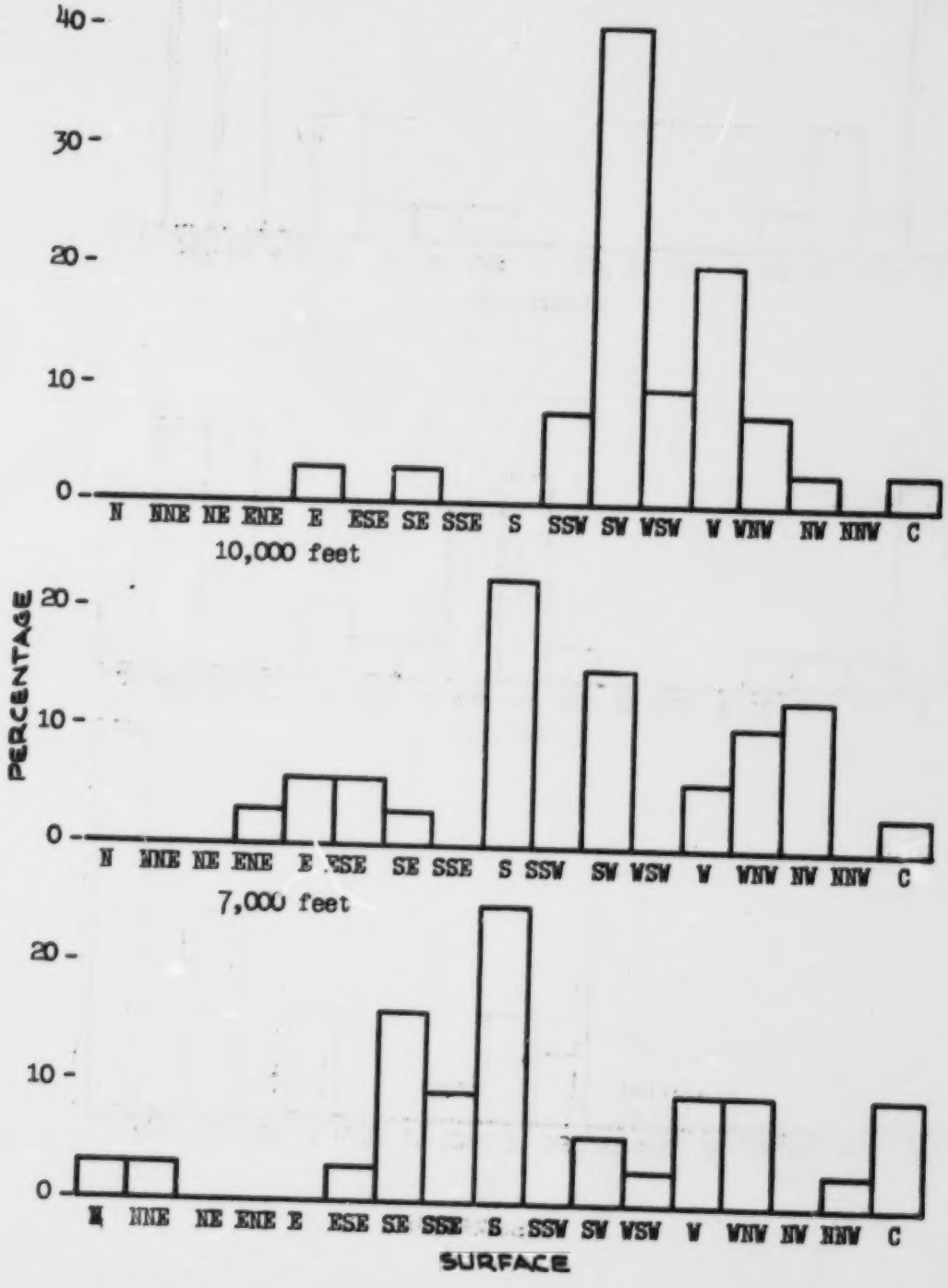

20
10
0
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
10,000 feet
PERCENTAGE
20
10
0
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
7,000 feet
20
10
0
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW C
SURFACE

FIGURE 13

FREQUENCY OF WIND DIRECTION WHEN INVERSIONS ARE PRESENT
UNDER THE INFLUENCE OF LOW PRESSURE



following results of inversions are applicable: The average magnitude of inversions is 7.1 F. while the thickness is 2400 ft.- a rise over the average 770 ft. There is also a predominance of skies with less than five-tenths clouds. With a high pressure surface system and a ridge aloft, 75% of the days showed inversion conditions.

In the situations of low pressure and trough aloft, the low center was over Eastern Nevada. The surface direction of wind had a more southerly component with an increase in velocity of an average of 5 knots. The upper air at the 7000 ft. level was from the southwest with a velocity of 12 knots. The 10,000 ft. level wind was also from the southwest with a velocity of 21 knots. The magnitude of the average inversions under these conditions was 3.7 F. with a sky cover of eight-tenths. The depth averaged 550 ft. which was considerably lower than standard climatological procedures indicated. Inversions occurred under these particular situations 43% of the time.

Therefore, it was concluded that the general statistical climatology of the area did not indicate the over-all picture of inversions. The synoptic climatology gave a more thorough interpretation of the situation.

THE AIR LAYER WITHIN WHICH THE INVERSIONS FORM

A. Maximum Temperature

When the effect of wind disturbance is excluded, the composition of air largely determines its ability to take up heat directly by absorption and indirectly by conduction from the underlying soil. The drop in density and moisture content of the air at higher altitudes results in the normal temperature lapse rate of about 1 Fahrenheit degree per 300 ft. This is sufficiently great to affect local climates in regions of strong relief. It was expected and found that the valley sites in Great Salt Lake Valley (4220 ft. elevation) registered consistently higher maximum temperature than the stations located to the east of the city at the University of Utah (4737 ft. elevation) and Red Butte Canyon and the higher slopes (5160 ft. elevation). The normal lapse rate which might be expected (about 2.5 Fahrenheit degrees for this difference in elevation) is exceeded throughout the ten-month period; the valley station being some 3 to 4 Fahrenheit degrees warmer in winter and 5 to 7 Fahrenheit degrees warmer in the summer. This excess is largely due to the physiography. It appears that the steepness of the valley sides directs reflected insolation on to the opposite side of the valley where it impinges a second time. The greater excess occurs during calm weather with cloudless skies and as would be expected the range was found to increase during summer months.

In addition to the altitude, aspect is believed to influence maximum temperatures. Theoretically the amount of solar radiation reaching a conical hill would be symmetrical with respect to the meridian, but the resulting temperature will be higher on a slope with a westerly exposure for two probable reasons: in the first place, the heating of the easterly facing slope has to start from the lower temperatures of morning whereas the westerly slope is already preheated prior to receipt of the afternoon radiation; secondly, much of the morning radiation is initially expended in evaporating moisture and so is not available for temperature increase. In consequence, highest temperatures may occur not where the aspect faces south but rather more to the west. This was shown in Red Butte by the frequent higher maximum recorded at station #4 near Red Butte.

In winter, the central city area is warmer by a degree or so than the surrounding country areas at similar elevation. Much is doubtless due to the increased heat generated by the city itself and the higher absorption rate permitted by the increased atmospheric pollution of winter months which also reduce outward radiation.

The greater local variations of the maximum occur under calm clear conditions in summer, but they do not reach the same magnitude as the variations associated with the minimum, and frequently under conditions of vigorous air movement, little or no difference was recorded over the area—even the normal temperature lapse rate was occasionally masked. Under foggy conditions in winter, the maximum may be affected

by valley inversions. Normally these inversions disappear before midday but sometimes the lower levels may be blanketed by a thick fog cover which fails to disperse with a feeble sun and shorter day. When this occurs, the hillside stations which have had bright sunny conditions record a maximum temperature several degrees higher than valley bottoms.

B. Minimum Temperature

The minimum temperatures which were recorded revealed two main temperature distributions, either of which might prevail on any given night according to the controlling circumstances. These will be called lapse and valley inversion distributions.

Lapse distributions were found under conditions of fairly vigorous air movement and cloudy skies. They were therefore frequently associated with the passage of a cyclone. Under this state of affairs, we find the normal temperature lapse rate which would be expected after taking into consideration the difference of altitude; thus there was usually a steady drop of almost 3 Fahrenheit degrees from the valley floor to the site of the higher observation stations.

Inversion distributions theoretically are associated with calm clear nights and low relative humidities. Hence they are more frequent during anticyclonic conditions. The existence of valley inversions has been realized for some time but few quantitative measurements have been conveniently assembled. It is shown here that inversions probably are more common in regions of diversified relief than has before been realized, and frequently occur when a moderate cloud cover and light

winds are present. Shaw (4) in 1955 stated that with light winds and a clear sky the inversions extend up to 1000 ft. with a magnitude exceeding 9 Fahrenheit degrees. A cloudy sky reduces the height to about 700 ft. without greatly affecting the magnitude of the inversion, but an overcast sky has a marked effect, bringing the inversion top down to 250 ft. and the magnitude of the inversion to 0.6 Fahrenheit degrees. Shaw also indicated that an overcast sky probably has a greater effect than indicated. The effect of increasing wind speed is to diminish the magnitude of the inversion, but under clear or cloudy conditions the height is not affected until the 15,000 ft. MSL wind exceeds 30 knots. The valley inversions were distributed throughout the year but showed a marked seasonal maximum in the winter months. One may assume this is partly due to the greater intensity permitted by the increased radiation of longer nights and smoky conditions in the valley. (See Figure 14)

The mean of the lapse nights revealed a definite correlation with altitude, and close agreement with the usual temperature lapse rate. The mean of the valley inversion nights shows that the valley was on an average some 3.5 Fahrenheit degrees colder than the University of Utah, and 5 Fahrenheit degrees colder than Red Butte Canyon on such nights.

FIGURE 14

MONTHLY OCCURRENCE OF INVERSIONS

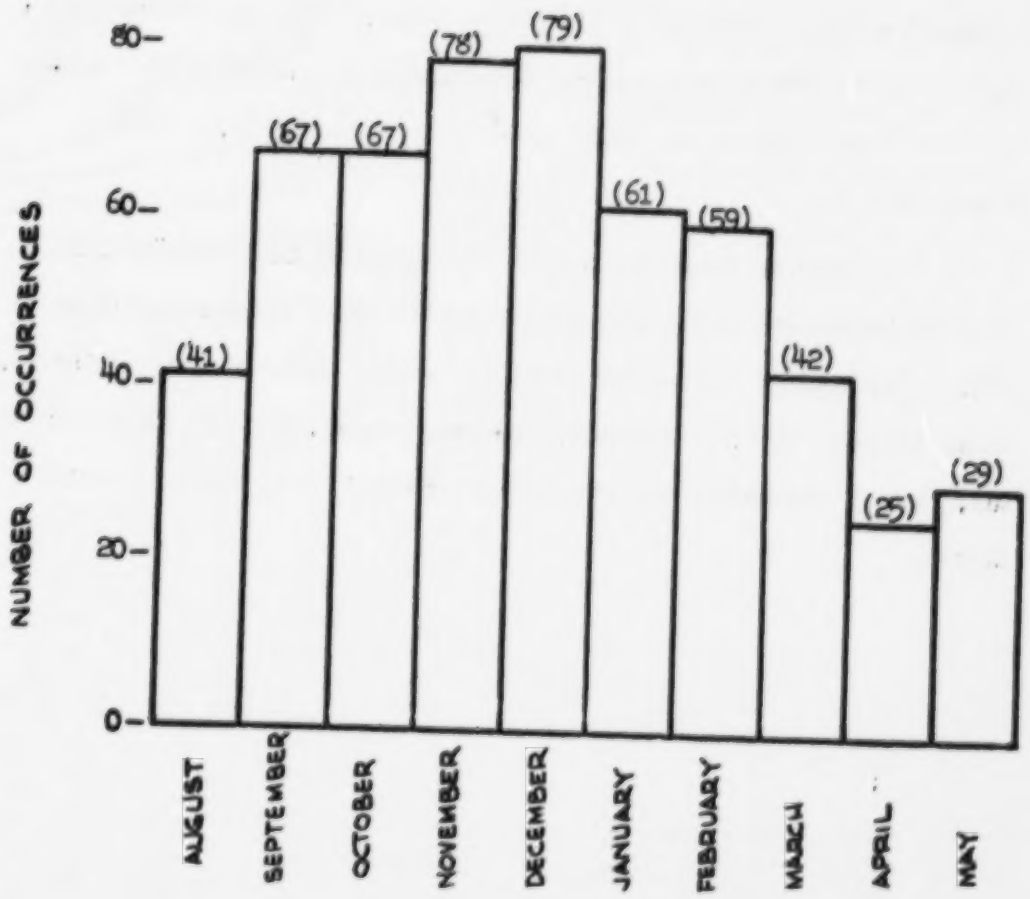


FIGURE 15

FREQUENCY BY HOUR OF INVERSIONS

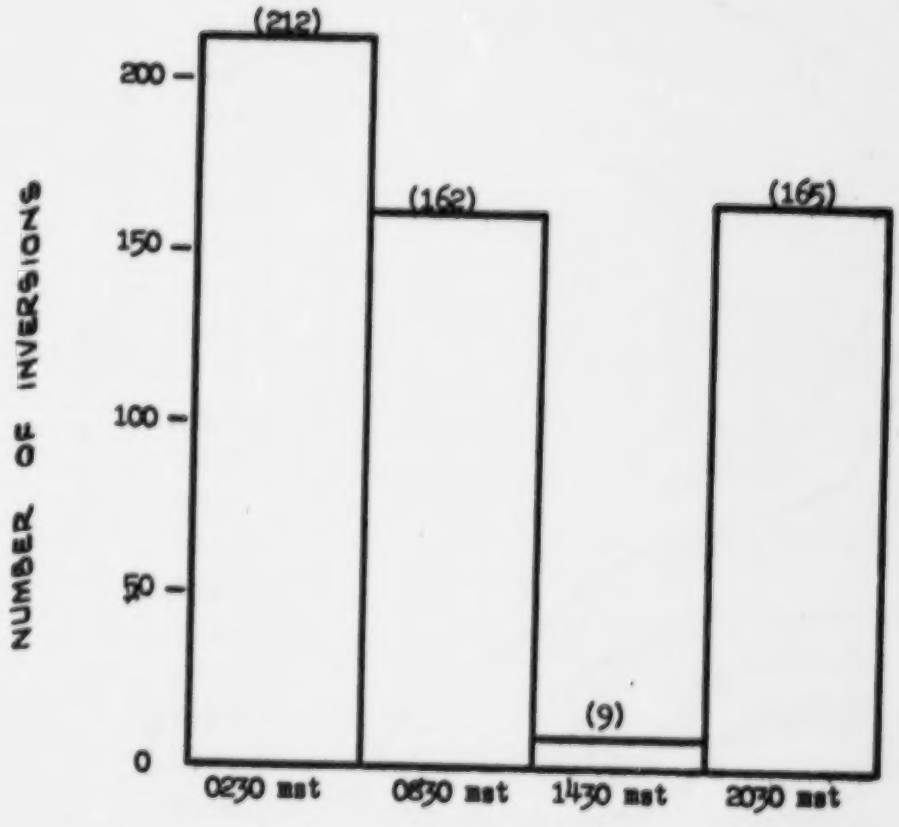


FIGURE 16

INVERSION-NIGHT
MAY 6, 1957
SLC (AIRPORT)
RED BUTTE #3
TEMPERATURE, DEGREES F.
80°
70°
60°
50°
40°
(TIME)
0128
0228
0328
0428
0528
0628
0728
0828
0928
1028
1128
1228
1328
1428
1528
1628
1728
1828
1928
2028
2128
2228
2328
0028

FIGURE 17

SLC (AIRPORT)
RED BUTTE
NORMAL NIGHT NON-INVERSION
MAY 8, 1957
(TIME)
0128
0228
0328
0428
0528
0628
0728
0828
0928
1028
1128
1228
1328
1428
1528
1628
1728
1828
1928
2028
2128
2228
2328
40°
50°
60°
70°
80°
TEMPERATURE DEGREES F.

The urban influence is very clearly seen in both the mean for lapse and for valley inversion distributions. Salt Lake City Corporation Power and Heating Division at Ninth South and Second West, representing the central city area, was higher in temperature than corresponding valley sites to the west throughout the observations. For normal conditions the retained heat of the city area keeps the minimum higher by 4 Fahrenheit degrees. For the valley inversion conditions the difference is slightly greater—some 4.5 Fahrenheit degrees. The retained warmth of the city frequently prevented the complete development of a valley inversion within and over the city when the upper and lower area of the valley was experiencing such conditions. As might be expected, this is more common in the summer months when valley inversions are more shallow and not so well developed as a result of shorter nights. (The terms "shallow" and "deep" will be used to express the height of the inversion top above the valley floor and not the temperature magnitude of the inversion.)

The most extreme minimum temperatures are generally recorded after a calm clear night with dry air (i.e., a low relative humidity) and snow cover. Such minimum temperatures are associated with winter inversions. Snow forms a good radiating surface and is at the same time a poor conductor of heat from the ground underneath. The extreme minima are also associated with the greatest range of temperature differences between the University of Utah, Red Butte Canyon and the valley site. Thus, in Salt Lake City during the snow cover of the last week in February and the first week in March, 1957, the University of

Utah recorded a minimum of 39 Fahrenheit degrees and the Weather Bureau at the Airport in the valley recorded a minimum of 27 Fahrenheit degrees—a difference of 12 Fahrenheit degrees.

These large differences were sometimes approached but never reached in the summer months when, despite the shorter nights, there is a big drop of temperature at night after overheating in the day. It is supposed that much cool air from the canyon drainage collects in the valley.

One of the more striking visible effects of a deep valley inversion is the formation of fog. Some of the shorter autumn and winter fogs are radiation fogs. These frequently accompany a valley inversion provided the air which collects in the valley bottom is cooled below the dew point temperature.

The meteorologist speaks of fog when the visibility is less than 1,100 yards; the public commonly refers to fog when the visibility is less than 100 yards. With the meteorological definition one can determine by a study of the twenty-six year climatological data of Salt Lake City that fog will accompany ten valley inversions yearly. The maximum intensity is reached in the winter period when anticyclonic conditions giving light winds, and clear night skies are combined with longer nights. The air is then cooled well below the dew point and a substantial fog layer is built up. The succeeding day insolation is feeble and of short duration in winter and the fog may then fail to be dissipated during the day and persist into the next night when it

becomes thicker. An example of this occurred in Salt Lake City during the first week of February, 1957, when the valley was enveloped continuously in fog for two days; the University of Utah and Red Butte Canyon experienced feeble sunshine. The inversion of the temperature was maintained continuously day and night throughout the period.

Fog persistence is related to the heating required to dissipate fog at different air temperatures. A considerable temperature rise is necessary at low temperatures, but when the air temperature is already high, a further slight increase will suffice to produce a rather dense fog.

The increased warmth of the city area was again frequently demonstrated during the winter fogs by a greater visibility in the center than in the outskirts; and on one or two occasions small cumulus-like clouds were observed from the University of Utah and Red Butte to be forming at the top of the fog immediately above the city and also to the west of the center of the city at Gadsby Power Plant.

The construction of the valley naturally tends to encourage ponding of the cold air and fog during inversions. Ponding was also noticeable when a very light north or northwest wind prevailed at the surface level.

Temperature inversions, whether accompanied by foggy conditions or not, are of great importance, especially in winter, in a city such as Salt Lake—nesting in a valley bottom. Their existence or non-existence explain why smoke and other pollutants accumulate and either

form or intensify fog on some days while on others the air is clear although the same amount of smoke is being produced. When not carried off horizontally by wind, the smoke is dispersed upwards in convection currents formed by the accompanying hot gases; when the temperature is inverted, the smoke will rise until it reaches the same air temperature and then it will spread out horizontally. This was frequently observed in the winter when the process greatly assisted the formation of fog. The summer was almost free from serious smoke pollution as valley inversions were shallow and less persistent and most of the smoke in Salt Lake City is derived from domestic fires which are but little used. Salt Lake City, already a clean city by comparison with some industrial areas, could practically eliminate smoke pollution if its inhabitants could be encouraged to use smokeless fuels, and to refrain from burning leaves. Of course, the importance of the smoke pollution emitted by some industrial sources must not be overlooked in this connection. Because of the greater warmth and smaller relative humidity of the city, a clean atmosphere could doubtless reduce the frequency of fogs in the city below that of the surrounding area.

As has been previously stated, hourly temperature was taken from thermograph observations at four locations in the Red Butte area, the University of Utah, downtown Salt Lake City, and the Weather Bureau at the Airport.

Three factors are very evident in an examination of these observations. These are: altitude, valley inversions and urban effect. Somewhat like the minimum considered above, one of two states existed: (1) lapse, when the usual temperature lapse rate prevailed and the Red Butte stations were some 2 to 3 Fahrenheit degrees lower than the valley sites—the difference being fairly consistent throughout the year, and (2) inversions, when the temperature distribution was reversed and the valley sites were colder than the slope sites, the magnitude of the difference varying according to the season. In winter the deeper and more persistent valley inversions were nearly always strongly in evidence at 0230 MST. Toward the end of December there is little difference between the minimum and the 0230 MST temperature. In summer, however, the valley inversions rarely lasted more than three hours after sunrise and disappeared before 0830 MST.

The city station revealed that superimposed upon these factors was the urban effect. Throughout the winter this station recorded a steady 1.5 to 2-Fahrenheit degrees more than might have been expected for its altitude, clearly indicating that the temperature was being kept up by the generated heat and retained warmth of the city. The result was that on lapse mornings the city station usually recorded some 4 Fahrenheit degrees warmer than the surrounding stations at Red Butte. Differences after a valley inversion night, depended, of course, on the severity of the inversion. There were clear indications that the city accelerated the break-up of a reversed temperature structure.

The urban effect in summer was not, however, so marked and the valley sites to the east frequently recorded temperatures at 0630 MST slightly in excess of the city center.

C. Relative Humidity

A continuous record of the relative humidity was kept at stations #3 and #4 at Red Butte Canyon. The University of Utah and the Weather Bureau at the Airport also used hair hygrographs. The relative humidity curve may be considered as a resultant of the absolute humidity and temperature curves, and since the take-up of water vapor also depends on its availability, the relative humidity may be looked upon as a function of three variables producing some complicated interactions. Diurnal variation in the relative humidity is in consequence not always the inverse of the temperature variation. High temperatures do not always mean low relative humidity and so on. It is then difficult to formulate generalizations for the factors of altitude differences and aspect difference between stations.

As might be expected, the distributions were much modified after nights of valley inversion. The Weather Bureau recorded relative humidities in excess of the hillside stations and under fog conditions, valley recordings were more frequently 100%. The city, however, usually experienced relative humidities a little lower than the valley, and this was evidently the urban effect manifesting itself again. In a built-up area, houses, pavements, roads, etc., will greatly reduce the amount of evaporation which lowers the absolute and relative humidities.

Towns also are frequently warmer (especially in winter) and this increase further depresses the relative humidity.

D. Winds

Continuous daily charts of wind velocity and direction were maintained at the University of Utah and the Weather Bureau, and a careful watch on katabatic effects was also maintained by the author.

Wind force had to be estimated at the Red Butte area and unlike the other observations previously enumerated, the personal element is more evident. Even so, there is a clear indication from the records of the effect of topography upon both wind direction and force. Calms were quite frequent at the lower levels but rare on the Red Butte slopes.

Previous observations by Hawkes (13) in 1947 suggested that local winds, mainly of the katabatic type, would also be in evidence in the Jordan valley. His results are summarized in Figures 15 to 23.

A careful watch was maintained by the author during the observation period and this revealed katabatic flows whenever conditions were favorable. On occasions, especially in the winter, the movement of cold air down the valley sides could be felt quite easily, but in the main the movement is so slow that some means of rendering it visible is necessary before the wind can be detected. Smoke was usually present in and around Salt Lake City. Together with inversion hazes viewed from above, the flow of smoke yielded some very interesting, though subjective, data.

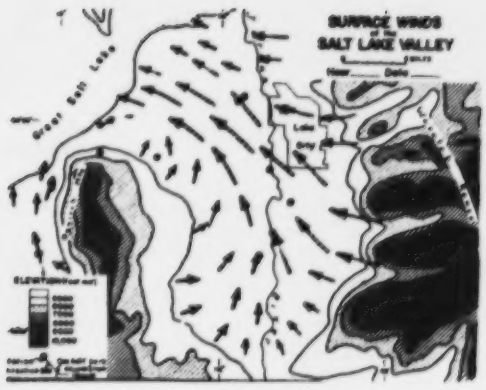


Figure 18. Hour, A. M.

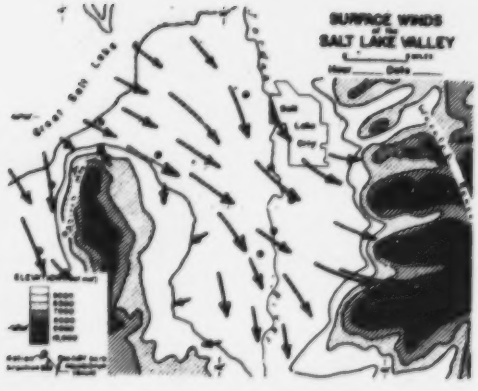


Figure 19. Hour, P. M.

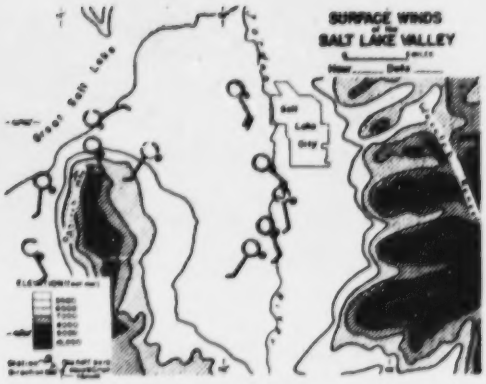


Figure 20. Hour, A. M.

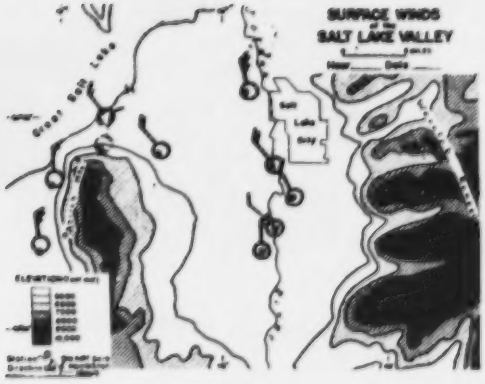


Figure 21. Hour, P. M.

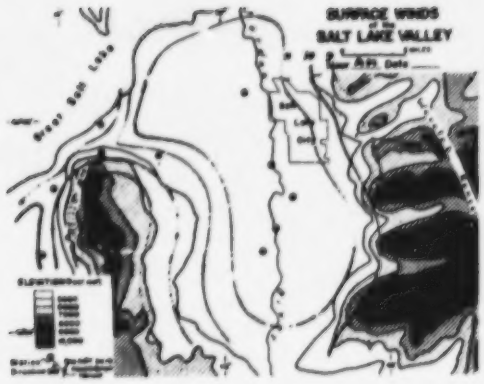


Figure 22. Time of wind shift. A. M.

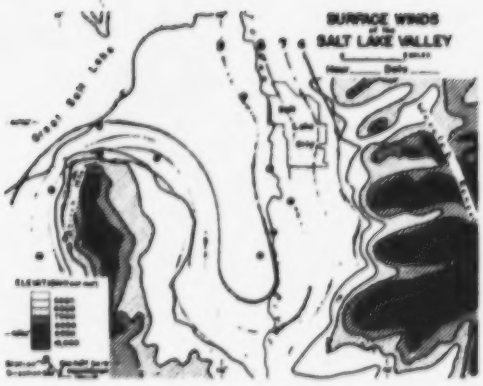


Figure 23. Time of wind shift, P. M.

Surface Wind Maps of Salt Lake Valley Compiled by H. Bowman Hawkes.

The more rapid the cooling of the ground, the stronger the resulting katabatic wind; snow covered slopes therefore greatly assist in producing the more extreme conditions. The gentle flow of colder air into the valleys was nearly always visible through smoke movement on calm nights, and could often be observed commencing around sunset. Usually the best indicator was smoke from the quarters at Fort Douglas, Red Butte area, and also the smoldering trash fire at Fort Douglas Dump, with much smoke and little heat. This dump was near the mouth of Red Butte Canyon, and would reveal the downward air drainage over a considerable distance. Chimney smoke from houses dotted over the hillside and valley was of great value when the valley inversion was developing rapidly or well established, but in shallow cases the chimneys were above the level of the katabatic movements, or if near the limit, the warmer air from the domestic fires rose above the level of the drift.

The inversion top was often clearly demarcated in the absence of fog by rising smoke spreading out horizontally. Early morning smoke in industrial areas up and down the valley was particularly useful in detecting shallow summer inversions.

The mass movement of the valley air in the morning was more turbulent than the katabatic flow down the valley sides, which seemed nearly laminar.

The pressure and density of the colder bottom air was frequently great enough for the air to flow against quite noticeable regional winds. One outstanding case, as reported in my daily record book, concerned the early morning and revealed, by smoke from a series of dispersed chimneys, air in the valley bottom moving down valley; half way up the valley sides air was moving down in the valley, while near the top of the slope and above the inversion level, there was a movement up from the southeast part of the valley in response to the local regional wind. The top levels of some inversions with distinct haze were also observed to be torn and ruffled when a light wind existed above the level of the inversion.

E. Regional Winds

When the winds associated with this nocturnal cooling process are reinforced by the large-scale circulation, the winds reach large proportions. Favorable synoptic situations are provided by a high atmospheric pressure area in Wyoming and/or vigorous low pressures are in western or southern Utah or in Arizona or southern Nevada. (14, 15, and 17) The surface regional winds blow predominantly from the southeast in the morning hours and from northwest in the afternoon. The upper air wind has a prevailing direction of south and southwest.

SALT LAKE CLIMATE AND HABITABILITY AS RELATED TO INVERSION CONDITIONS

A study of the effect of the climatic variations upon human living conditions opens an interesting door to a better understanding and appreciation of special climatological conditions.

The body normally maintains in the deeper tissues a temperature of 98.6°F. Heat is continually being generated by internal metabolism and this heat is conducted away to the skin where the temperature is lower than the deeper tissues. There it is dissipated by various means. The feeling of pleasantness depends largely upon the maintenance of the body at the normal temperature and the efficient removal of surplus heat.

In hot weather the loss of surplus body heat may be increased by limiting the clothing, by decreasing the air temperature, or by increasing the air movement. Conversely in cold weather heat may be prevented from escaping by wearing more clothing, by increasing the temperature, or by decreasing the air movement.

When exposed to cold, the skin temperature of the normal person falls and there is an onset of shivering—involuntary muscular movements which generate heat in an attempt to make up the deficiency. When exposed to heat, the efficient loss of surplus body heat is held up until the sweat glands discharge sweat which, in evaporating, takes heat from the body. Heat is then lost by radiation, by convection (air currents) and by evaporation.

Now consider the broad climatic divisions of valley, hill and urban sites in Salt Lake City in relationship with the principles of human comfort sketched out above.

A. Summer

In the greater heat of summer the human body will feel more pleasant when it is losing heat more rapidly and, in consequence, fares better where temperatures are lower and where there is a greater air movement. A low relative humidity will also assist more rapid evaporation. Under normal summer conditions, the lower temperatures and greater air movement of the hill sites are more pleasing than the temperatures and stuffier, calm conditions of the valley. It is true that relative humidity may be slightly greater at hillside levels than in the valley bottom, but this is more than compensated for by the increased air movement. When valley inversion conditions prevail (confined to night periods in summer), the valley has the cooler, damper air, but when the temperature is high, as in summer, the increased humidity resulting from a slight fall in temperature may neutralize the reduction and create an oppressive atmosphere. The hill sites with slightly warmer but drier air plus the greater air movement are again to be preferred to the valley sites, although there is perhaps less difference than for the normal day condition.

The effect of urban climate may best be considered by making comparison with valley sites at the same altitude. Under normal temperature structures, it can be seen that the city may be very

slightly cooler in summer but any small advantage that this gives is more than lost by the great reduction in air movement caused by the buildings. On the other hand, the city is frequently better than the remainder of the valley in inversions, for although temperature in this case is slightly higher than the valley, the humidity is kept down and the air feels less oppressive.

Summarizing for summer we have the following results:

	Increasing pleasantness→
Lapse states:	City → Valley → Hill→
Inversion states:	Valley → City → Hill→

B. Winter

In winter the body will be concerned with seeking an environment where temperatures are higher and air movement reduced. Humidity should be moderate. If the air moisture content is too high, it will be raw; if it is too low, the air feels dismal. Under normal conditions the higher temperature and calmer states will be provided by the valley; hillside sites are very much exposed and the strong cold winds sweeping across them make an unpleasant environment. Moreover, relative humidities are higher on hillside sites and the air feels raw in comparison with the valley. Valley inversions, however, reverse this picture completely. The valley now experiences lower temperatures and cold, damp air with frequent relative humidities of 80% or higher. In contrast the hillside will be basking in brilliant, if feeble, sunshine and the hillside will be warmer and calm.

Considering the urban factor and comparing with adjacent valley sites it will be remembered that in normal temperature structures, the city area is warmer in winter and has a reduced air movement. It is hence a more pleasant environment. The problem becomes a little more complex when inversion structures prevail, for while the greater warmth of the city helps to offset the lower temperatures, and prevent the formation of fog, smoke pollution is present in winter and works against this tendancy. Once the inversion is established, smoke pollution tends to aggravate conditions even more. At present, the city is, as a whole, less agreeable than the surrounding valley sites, under inversion conditions, but the position could be reversed if smoke pollution were eliminated.

Summarizing for winter we have, therefore:

	Increasing pleasantness →
Normal states:	Hill → Valley → City →
Inversion states:	City → Valley → Hill →

Bearing in mind the proportion of normal to inversion days (about 1 to 2) and the greater intensity of winter inversions, it is clear that on the whole hillsites emerge as the better situations, for they only suffer one defect—the raw cold winds of normal winter days. Optimum conditions probably exist where shelter can be found from these winds and locations away from the canyon mouth are perhaps ideal—such sites would coincide with the warm or thermal belt which is often found in winter inversions. It is perhaps significant that some of the better

class residential areas in Salt Lake City actually lie in this intermediate zone.

While the normal individual is adaptable to these local variations and can experience them without much discomfort, one should not lose sight of the important functions of Salt Lake City as a holiday center and a place of retirement. For borderline cases and for those of ill health, it is suggested that full regard ought to be paid to the microclimate factors, a subject which also has relevance to town planning, particularly with reference to problems such as smoke pollution and the building sites of further industrial establishments.

C O N C L U S I O N

A study of the climatology of local Salt Lake inversions was undertaken with consideration given to factors of magnitude and depth of inversion, sky cover, temperature, wind direction and velocity at the surface, 7000 ft. and 10,000 ft. levels. The above factors were also considered with relationship to synoptic situations.

The factors were studied in an attempt to classify the inversion patterns of this area. The results of the study revealed many things: The cloudy sky has little effect on the lowering of the top of the inversion. Cloudy skies lower the magnitude of the inversion.

The effect of increasing wind speed is less regular, although moderate winds tend to diminish the magnitude of the inversion. Wind direction has little influence upon inversions.

On the average, inversions occurred more frequently and with greater depths in the winter months. They also occurred in both cyclonic and anti-cyclonic situations. (The greatest inversion was observed 20 F. with a depth of 345 ft.)

It has been concluded that synoptic climatology is important for interpreting local inversion conditions.

Anticyclonic situations seem to favor inversions. Seventy-five per cent of the time under an anticyclone condition inversions were reported, while the cyclonic situation revealed that inversions occurred only forty-three per cent of the time.

The average height of the base of inversions was 770 ft. Intense shallow inversions usually formed in early evening. The greatest frequency of inversions was found to be shortly after midnight.

This work also showed the results of a study of the climatology of the Salt Lake Valley with special regard to inversions and medical climatology.

SELECTED BIBLIOGRAPHY

1. Johnson, N.K.: "A Study of the Vertical Gradient of Temperature Near the Ground", Geophysical Memoirs, Number 46, 1929.

2. Steiner, Rudolph Otto: "Zur Entstehung Von Bodeninversionen bei Wolkenlasen Himmel und Landwind", (On the Formation of Surface Inversions with Clear Skies and a Land Breeze). Rostock Universitat, Luftwarte, Wissenschaftliche Abhandlugen, Heft 1, 1929.

3. Johnson, N.K. and Heywood, G.S.P.: "An Investigation of the Lapse Rate of Temperature in the Lowest Hundred Metres of the Atmosphere". Geophysical Memoirs, Number 9, 1938.

4. Shaw, J.B.: "Vertical Temperature Gradient in the First Two-thousand Feet". Meteorological Magazine, London, Volume 84, 1955.

5. Cox, H.J.: "Thermal Belts and Inversions of Temperature in the North Carolina Mountain Region", Monthly Weather Review, Volume 49, 1921.

6. Young, Floyd D.: "Nocturnal Temperature Inversions in Oregon and California". Monthly Weather Review, Volume 49, 1921.

7. United States Weather Bureau: "A Meteorological Survey of the Oak Ridge Area". United States Atomic Energy Commission, ORO-99, 1953.

8. Shearer, Donald L.: "General Climatology of Dugway Proving Ground". United States Dugway Proving Ground, Utah, - Meteorological Division; Climatological Report, Number 2, 1956.

9. Marsell, R.E.: "The Geology of the Wasatch Mountains Near Salt Lake City", Compass, Volume 31, Number 2, 1953.

10. Fenneman, N.M.: Physiography of the Western United States, McGraw-Hill Book Company, New York, 1931.

11. Petterssen, Sverre, Weather Analysis and Forecasting, Volume 2, McGraw-Hill Book Company, New York, 1956.

12. Geiger, Rodolph: The Climate Near the Ground, Harvard University Press, Cambridge, Mass., 1950.

13. Hawkes, H.B.: "Katabatic Winds of the Great Basin", unpublished Ph.D. thesis, The Ohio State University, 1947.

14. Williams, Phillip,: "Wasatch Winds of Northwest Utah", Weatherwise, Volume 5, Number 6 , American Meteorological Society, Boston, 1952.

15. Hales, W.B.: "Canyon Winds of the Wasatch Mountains", Bulletin of the American Meteorological Society, Volume 14, 1933.

16. Defant, F.,: "Local Winds", Compendium of Meteorology, American Meteorological Society, Boston, 1951.

17. Eddy, Richard L.: "Canyon Winds at Hill Air Force Base, Utah", unpublished M.S. thesis, the University of Utah, June 1957.

18. Conrad, and Pollak,: Methods in Climatology, Harvard University Press, 1950.

19. Ezekial, Mordecai: Methods of Correlation Analysis, 2nd Edition, John Wiley and Sons, Inc., New York, 1950.

20. Guilford, J.P.: Fundamental Statistics in Psychology and Education, McGraw-Hill Book Company, New York, 1950.

21. Brooks, C.E.P., and N. Carruthers: Handbook of Statistical Methods in Meteorology, Her Majesty's Stationery Office, London, 1953.

APPENDIX

TABLE 4

INVERSIONS WITH WIND VELOCITY
TWENTY KNOTS OR OVER

Time	Date	°F.	Speed	7,000 ft.	10,000 ft.
0230 MST					
	8-17	4	20	SSE	W
	8-20	7	20	SW	NW
	8-27	10	30	NNW	WNW
0830 MST	8-26	3	10	S	SSE
1430 MST	None				
2030 MST	8-15	3	20	SSE	E
	8-30	1	30	NNW	NW
0230 MST	9-8	2	35	SSE	S
	9-12	5	20	S	SSW
	9-13	8	20	SSW	SW
	9-14	6	25	S	SW
	9-29	3	29	N	NW
	9-30	11	20	S	SW
0830 MST	9-7	4	20	SSW	S
	9-11	2	25	SSW	SW
	9-14	2	20	SSW	SW
	9-20	5	25	S	S
	9-26	4	20	S	SW
	9-27	5	20	SW	SW
1430 MST	None				
2030 MST	9-16	7	20	NE	SW
0230 MST	10-11	2	35	SSW	SW
	10-19	9	20	NW	WNW
	10-21	11	20	S	SW
	10-26	3	30	SSW	SW
	10-27	6	45	SSE	SSW

TABLE 4 (cont'd)

Time	Date	°F.	Speed	7,000 ft.	10,000 ft.
0840 MST	10-9	2	20	SSE	SSW
	10-10	5	20	SSW	SW
	10-11	1	35	SSW	SSW
	10-21	7	20	SSW	SW
	10-26	3	25	SSW	SW
1430 MST	None				
2030 MST	10-7	4	20	SW	S
	10-19	7	30	NW	WNW
	10-20	3	20	SW	W
	10-22	5	40	SSW	SW
	10-23	6	30	NW	WNW
	10-25	1	20	SW	SW
	10-30	3	40	S	S
0230 MST	11-13	13	25	SSW	SW
0830 MST	11-10	8	25	WNW	WNW
	11-13	9	20	SW	SW
	11-18	5	20	WNW	W
1430 MST	None				
2030 MST	11-12	8	20	S	SW
	11-13	8	25	NNW	C
0230 MST	12-4	1	30	S	W
	12-6	1	20	W	W
	12-11	6	20	SW	NW
0830 MST	12-4	4	30	SW	SW
	12-11	4	20	SW	WSW
	12-21	2	20	SSW	SW
	12-22	1	25	NW	NW
1430 MST	12-11	1	25	WSW	WNW
2030 MST	12-4	7	50	S	SW
	12-11	5	45	NW	NW
	12-15	2	25	SSW	W
	12-21	2	20	NW	NW

TABLE 4 (cont'd)

Time	Date	°F.	Speed	7,000 ft.	10,000 ft.
0230 MST	1-2	8	20	SE	SSW
	1-12	7	25	SSE	SW
	1-19	3	20	SSW	SW
	1-20	3	35	S	SW
	1-23	4	20	S	SW
0830 MST	1-2	6	30	SW	WSW
	1-8	5	20	SSW	SW
	1-10	3	20	S	SSW
	1-11	9	35	S	SSW
	1-12	9	20	SSW	SSW
	1-13	1	35	S	SW
1430 MST	1-12	2	25	SSW	SSW
2030 MST	1-1	6	20	SE	SSW
	1-10	5	20	S	SW
	1-11	3	25	S	S
	1-12	7	25	S	SW
	1-13	4	20	S	SW
	1-15	1	20	W	WNW
	1-19	4	30	SSW	W
0230 MST	2-7	2	20	S	WSW
	2-8	1	30	SSW	SW
	2-11	4	20	S	SW
	2-20	9	20	SSW	SW
	2-23	1	40	S	S
0830 MST	2-1	5	25	SW	SW
	2-9	3	20	NW	NW
1430	None				
2030 MST	2-10	2	20	S	SW
	2-23	2	30	SW	SW

TABLE 4 (cont'd)

Time	Date	°F.	Speed	7,000 ft.	10,000 ft.
0230 MST	3-9	3	35	S	SW
	3-16	5	35	S	SSW
	3-28	4	20	SSW	SW
0830 MST	3-9	2	50	S	SSW
	3-16	2	30	S	SSW
1430 MST	None				
2030 MST	3-9	2	25	SW	SW
	3-15	1	20	S	S
	3-16	2	20	S	S
0230 MST	4-14	4	25	S	SSE
	4-30	1	20	S	S
0830 MST	4-14	10	35	S	SSW
1430 MST	None				
2030 MST	4-24	3	20	NW	NW
0230 MST	5-1	3	25	S	SW
	5-2	2	35	SSE	S
	5-7	2	35	SE	SSW
	5-10	2	20	S	SSE
	5-11	3	25	SSW	SSW
0830 MST	5-6	2	25	S	SW
1430 MST	None				
2030 MST	5-1	2	20	SSE	S
	5-2	4	25	S	SSW
	5-6	2	30	SSW	S
	5-29	1	20	SE	S

TABLE 5

WIND DIRECTION AT SURFACE DURING INVERSIONS

(0230)

MST

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August			2		2		14	8	5								
September	1					1	10	14	4								
October	3				1	2	10	8	4						1	1	1
November	1				1	1	11	6	4	1			1				4
December		1				1	8	7	2	1			2	1		2	6
January	2						4	7	5	1	2		1	2	2	1	4
February					1	3	5	5	7				1			2	4
March	2						5	12	2	3	1			2	2		2
April	2	1	1			1	6	8	1		3		2	2	1		2
May							10	7	6	1	1			1		1	2
TOTALS	11	2	3		5	9	83	82	4	7	7		7	8	6	7	27

TABLE 5 (cont'd)

WIND DIRECTION AT SURFACE DURING INVERSIONS

(0830)
MST

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	1	1				2	8	12	4	1	1				1		
September	1					1	14	5	3	1			1			3	1
October	1			1	1		8	10	5			1		1		3	
November		1	1				13	8	2	2			2				1
December	1				1	2	7	7	6			1	2			1	3
January	1					1	8	3	4		5		2	2		1	4
February						1	7	6	12						1		1
March	2	1	1		1	2	7	7	5			1	1	1	2		
April	5					1	5	3	1	4			1		4	3	3
May	—	1	—	—	—	2	8	5	6	—	—	1	1	3	3	—	1
TOTALS	12	4	2	1	3	12	85	66	48	8	6	4	10	7	11	11	14

TABLE 5 (cont'd)

WIND DIRECTION AT SURFACE DURING INVERSIONS
(1430 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	1		1		1		1	2	3		3						
September	6	1					1	3	4								
October	3	2			1	1		3	4		1	1	2	1	8	4	
November	4	2			1			2	2					6	6	6	1
December								5	3	1		1	3	5	12	1	
January	3						1	4	2		2	2	1	2	10	2	2
February	2		1					1	5	4	1		2	2	3	7	
March	1						3	7					3	4	4	8	1
April	2		1		1	1	1	3	1		1	1	1	3	8	5	1
May	6	2		1	1	1		5	4	1	2	1	1	2	4	1	
TOTALS	28	7	3	1	5	2	4	31	35	6	10	6	16	26	73	46	5

TABLE 5 (cont'd)

WIND DIRECTION AT SURFACE DURING INVERSIONS
(2030 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	4		2	1	1	1	9	5	3	2	1	1				1	
September	1		1		1	3	7	6	7		1	1			1	1	
October						1	8	6	7		2	1	1	2	1	2	
November	2	1				11	5	11	5					1	1		3
December	2		1		1	1	5	6	4				1		1	2	7
January	1	2	1		1	2	4	4	4		1	1	5		1	2	2
February	1	1					6	1	7	1	2			2		1	6
March	2	1				2	3	6	3		1			2	1	4	6
April	1	3	1	1	2	3	4	4	1		2		1		1		6
May	1	1	1	1	-	-	5	7	1	1	-	1	2	3	2	-	5
TOTALS	15	9	7	3	6	14	56	56	42	4	10	5	10	10	9	13	35

TABLE 5 (cont'd)

WIND DIRECTION AT 7000 FT. DURING INVERSIONS
(0230 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	1				1	2	2	4	8	3	2		1	1	3	3	
September	1	3	2		1	1	1	3	5	5	1		1		3	1	2
October		1			1		2	3	10	3	4		2		5		
November	4		2		3	1			4	2	3		2	1	6	1	1
December	2								8	2	3	2	3		5	4	2
January	2			1			4	22	6	4	8		1	2		1	
February			1						9	7	3		3	1	2		2
March	2				1	1	1	1	6	4	2		2	2	7	2	
April	3		3			1	1	1	7	2	1	1	2		5	3	
May	1	2	2	-	2	-	3	1	9	2	2	1	1	1	3	1	-
TOTALS	16	6	10	1	9	6	14	15	72	34	29	4	18	8	39	16	7

TABLE 5 (cont'd)

WIND DIRECTION AT 7000 FT. DURING INVERSIONS
(0830 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August							1	2	15	3	3	1	2	1	2	1	
September							4		12	3	3			4	2	1	1
October	1	1					2	6	5	7	2			2	4	1	
November	4		1				2	1	3	2	6	2		3	2	3	1
December		1	1				2	1	4	4	7		3		6	1	1
January			2		1		1	2	5	6	4	1	1	4	2		2
February	1				1		2		3	4	10		2		3		2
March	1	1					1	2	3	4	7	2			8		2
April		1	3		1		3		3	1	3		2		5	4	2
May	2		2		2	2	4	1	7	3	1	1	2	2			2
TOTALS	9	3	12		5	2	22	15	61	37	46	7	12	16	34	11	13

TABLE 5 (cont'd)

WIND DIRECTION AT 7000 FT. DURING INVERSIONS
(1430 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	1	1	2	1				1	4	3	4	1	1	1	7	2	2
September	2							1	6	3	3		1	2	7	3	2
October							1		8	5	3	1	2	1	6	1	2
November	3		3				1		3		4	1		1	8	2	4
December	3		1	1					2	4	3	1	3	1	9	3	
January			1		2	1			10	2	4		4	2	4		1
February		1		1				1	6	8	4		2	1	2	1	1
March	2	1	1				2		4	2	6		4	1	6		2
April		2	11		2			2	3	3		1	2	10	4		
May	1		1	1	1		1	4	4	3	2	1	4	1	6	2	
TOTALS	12	5	10	3	5	1	5	9	51	33	33	5	22	13	65	18	14

TABLE 5 (cont'd)

WIND DIRECTION AT 7000 FT. DURING INVERSIONS
(2030 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	2		6		1	1	1	3		2	1	1	3	1	4	3	2
September	3		5				1	4	3	2			2		5		5
October	3		3	1					3	1	7	1	1		5	3	3
November	4	3	1		1		1		2	1	3		2	1	10	2	1
December	4	1	1				1	2	3	1	2		1	2	7	3	3
January		1				3	1	1	10	2	5	1	2	1	2		2
February		1	1		1	1			8	1	8		1		2	2	2
March	3				1				6	3	6	1	1	2	6	2	
April	1	2	3				1	2	3		5		1		6	3	3
May	2	1	1	_	1	1	4	2	5	2	2	1	1	2	3	3	_
TOTALS	22	9	21	1	5	6	10	14	43	15	39	5	15	9	48	21	21

TABLE 5 (cont'd)

WIND DIRECTION AT 10,000 FT. DURING INVERSIONS
(0230 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August			1		1		1	1	4	6	3	2	2	3	4	2	
September	1	1	1			1		1	1	2	9	1	3	2	6		1
October							1	2	2	5	10		4	4	3		
November	3	2	2			1					1		3	5	9	4	1
December	3	1	1						1		4	1	4	3	8	5	
January		1					1		2	4	9	4	3	3	2	2	
February					1				1	1	5	4	9	4	2		1
March	2							3	1	3	6		3		10	3	
April	2		2	1		1		1	4	1	1	3		3	10	1	
May	2	2	1			2	1	3	4	6	4		2	2	3	1	
TOTALS	11	7	8	1	2	5	4	11	20	28	52	15	33	29	57	18	3

TABLE 5 (cont'd)

WIND DIRECTION AT 10,000 FT. DURING INVERSIONS
(0830 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	2		1					4	1	5	6	2	4	2	2	2	
September		1					1		3	1	9	2	6	1	5		1
October					1		1		2	6	11			3	6	1	
November	5	1	2		1						3		3	5	7	2	1
December	1	1	3								4	1	5	4	8	4	
January	1	1		1					1	3	8	3	6	2	1	1	3
February			1	1						1	9	1	6	5	4		
March	1	1						1	2	2	4	1	6	3	7	1	2
April	1	1	2	1			2	1	1	2	2	2	4	2	5	3	1
May	1	3	3	-	1		1	-	5	4	6	1	-	3	2	1	-
TOTALS	12	9	12	3	3		5	6	15	24	62	13	40	30	47	15	8

TABLE 5 (cont'd)

WIND DIRECTION AT 10,000 FT. DURING INVERSIONS
(1430 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August									3	10	4	3	1	3	2	1	4
September								2	5	2	7	3	4	2	3		2
October								3	5	4	11	3	2		3		
November	3	3	3								1		4	1	11	1	3
December	4	1	1	1						1	1		4	7	6	4	1
January	1				1				1	6	8	1	5	3	3	1	1
February		1			1					6	8	1	4	1	5		1
March	1				1		2	2	3	1	5	2	3	4	4	1	2
April	1		3				2	2	1		4	2	5	4	5	1	
May	2	1		2		1	2	6	3	6	1	2	3	2			
TOTALS	10	7	8	1	5	5	11	24	33	55	16	34	28	44	9	14	

TABLE 5 (cont'd)

WIND DIRECTION AT 10,000 FT. DURING INVERSIONS
(2030 MST)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	C
August	1		1		2	1	1	3	1		4	2	5	1	6	2	1
September			1				1			4	9	4	4		5		2
October		2	1		1		1		3	3	6	2	6	3			3
November	3	2	4		1						2		2		11	3	2
December	4	2	1							2	3		3	3	10	3	
January		1							2	2	12	2	5	2	3	1	1
February			2						2	2	6	3	5	1	3	2	3
March	1					1		1	3	2	4		5	4	8	2	
April	1	1	2		1				3		5	2	2	1	8	2	2
May			1	1	1	1	1	3	7	3	1	2	3	2	3	2	
TOTALS	10	8	13	1	6	3	4	7	21	17	52	17	40	17	57	17	14

TABLE 6

NUMBER OF INVERSIONS PER MONTH

	0230 MST	0830 MST	1430 MST	2030 MST	Total
August	18	7	1	15	41
September	24	24	1	18	67
October	21	22	0	24	67
November	28	26	1	23	78
December	27	25	3	24	79
January	20	18	2	21	61
February	23	20	0	16	59
March	17	15	1	9	42
April	16	3	0	6	25
May	18	2	0	9	29
TOTALS	212	162	9	165	548

TABLE 7

WIND DIRECTION WITH INVERSIONS 20 KNOTS AT 7000 FT.

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0230 MST	1						2	6	15	9	2		1		1	1
0830 MST								1	10	10	6			2	2	
1430 MST										1		1				
2030 MST			1				2	2	11	4	6		1		5	2
TOTALS	1		1				4	9	36	24	14	1	2	2	8	3

WIND DIRECTION WITH INVERSIONS 40 KNOTS AT 7000 FT.

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0230 MST								1	1							
0830 MST									1							
1430 MST																
2030 MST									1	1					1	
TOTALS								1	3	1					1	